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Comparing Medium Poly Workflow with Traditional Workflow

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ABSTRACT

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3D environment design for games begins by choosing a suitable workflow considering the technical limitations as well as the desired visual style. This thesis is a comparative study and a research into a contemporary 3D environment creation workflow called medium poly workflow. The purpose of the comparative study is to highlight the differences between medium poly workflow and a traditional baking 3D modeling workflow. Research into both workflows and the current visibility of the medium poly workflow in games was carried out.

A research project was created alongside this thesis in order to aid in the comparative study. This project was a small 3D environment created by using each of the workflows separately in order to define the differences of each workflow at different stages. The creation process of the environment was broken down to the different stages of each workflow.

The comparative study brought to light the iterative flexibility and the increase in visual fidelity when using the medium poly workflow. The increase in rendering performance was visible as well. The research gave an understanding into the significant differences of the workflows as well as the benefits of each, making them evident throughout the process.

Key words: workflow, medium poly, decals, optimization, 3D environment design

CONTENTS

GLOSSARY

3D	Three dimensional in a virtual environment
4k	Refers to a resolution of image or video that is approximately 4,000 by 4.000 pixels in size.
AAA	Often pronounced as triple-A is a classification for video games produced by a major publisher
Alpha	Opacity of a pixel in a digital image
Asset	Finished 3D art component.
Baking	Process of rendering 3D features into textures.
Blockout	Placeholder assets for preview
Edge	A connection between two vertices that works as a building block for polygon meshes
Environment	Combination of assets that realise a gameplay location
Environment artist	An artist specialised in creating environment assets
Face	A closed connection of edges that works as a building block for polygon meshes
Geometry	3D shapes form
High poly	A high detail polygon mesh.
Interior	The inside of an enclosed structure
Iteration	Refining and modifying something by creating different versions of it
Low poly	A polygon mesh that is relatively low in detail
Material	The visual representation of combined textures in a in rendered output
PBR	Short for Physically based rendering, is a Realtime 3D rendering technology that accurately models the behaviour of light and surfaces
Polygon	A coplanar set of faces
Polygon mesh	Also referred to as a mesh, a collection of vertices, edges and faces that define the shape of a 3d object.
Post-processing	Effects after the 3D rendering
Primitive	3D building block made of basic geometric forms
Realtime engine	Software that is used to realise the creation of 3D games

Shader	Calculates how a material is rendered on screen
Texel density	The scale of individual polygons or UV islands compared to the size of texture pixels per meter of real size
Texture	Image that is projected on a model as surface detail
Texture Atlas	Textures combined on to a single image
Texture memory	Computer memory allocated for the storage of image textures
Tileable texture	A texture map that can be tiled seamlessly on a surface multiple times along the X and Y axis
Trim sheet	A texture that can be used in combination for multiple models
UV	A two-dimensional coordinate defining the position of texture maps on surface of the model
Vertex	A singular position usually in 3D space that works as a building block for polygon meshes
Workflow	A repeatable pattern of activity that can be broken into steps

1 INTRODUCTION

3D environment creation is a combination of artistic skill with technical knowledge. The modern-day advancements in the different techniques and technologies enable more artistic freedom to create believable and realistic environments. New iterative workflows enable the artist to continuously achieve higher standards that in turn also affect the consumers expectations of these environments. 3D environments have begun to parallel cinematic quality and artist have the responsibility to keep up with the demands of high-quality assets.

A medium poly mesh is a 3D model that is between a high poly mesh, created with the most visual detail, and a low poly mesh that is created as silhouette like detail, often only showing the form of the object without details. In a traditional workflow the high poly mesh details are baked onto a low poly mesh as a unique texture to preserve detail. The medium poly mesh often has bevelled edges that use face weighted normals to simulate the visual fidelity of a high poly mesh. These bevels negate the need for an actual texture and thus allows a faster and non-destructive workflow with tileable textures. The details are added using mesh decals that are meshes that lay on top of the mesh using low resolution textures.

The emergence of medium poly workflow with decals has given the tools to create modular yet highly customizable and detailed environments for games. This technique has been harnessed in a handful of games to this day but is also present to a lesser extent in a larger variety of games. The workflow has been taken advantage of in games such as Alien: Isolation and more recently DOOM: Eternal. I will be investigating their implementation of the medium poly workflow in the mentioned games and the benefits from their perspective. A comparative study will be made comparing the medium poly workflow with a more traditional workflow. A small 3D environment will be created to aid in the comparative study. The findings from the practical project will be presented from a technical standpoint and considering graphical fidelity and possibilities for iteration.

2 WORKFLOW OVERVIEW

2.1 Traditional workflow

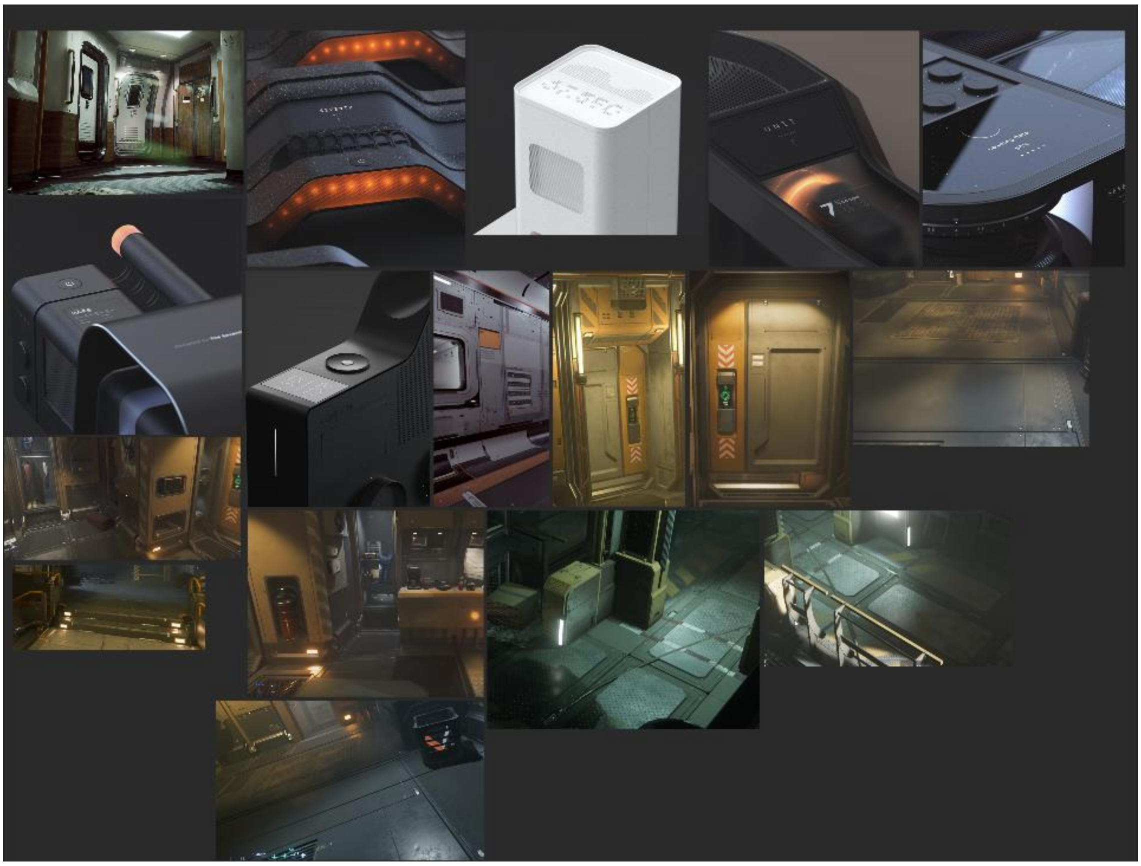
Before going into medium poly workflow in detail, let us dive into how 3D environments are traditionally made and the steps that are usually taken to create a 3D environment. By traditional workflow I mean a workflow that is mostly the standard starting point when starting out as a 3D modeler. The base of the workflow has remained the same, but the tools have changed a lot. Making the traditional workflow more artist friendly.

The basis for the traditional workflow was first introduced by Krishnamurthy and Levoy in 1996, at a SIGGRAPH conference. Where they introduced the idea of taking geometric details from high polygon model and baking them on to low poly models, using displacement maps (Krishnamurthy & Levoy, 1996). This was taken further when the idea of storing the surface normals directly onto a texture map was introduced (Cohen & Olano & Manocha, 1998). Eventually the idea of decoupling the high and low polygon meshes was introduced (Cignoni & Montani & Rocchini & Scopigno, 1998). This laid out the basis for the traditional workflow of baking details from high poly to low poly and is still used to this day in multiple workflows.

This is an overview of the process that an artist goes through when creating 3D-models for an environment using a traditional workflow. Every artist has deviation in their workflow, but for the comparison I will take on a more high-level approach. As the process itself consists of certain steps that are similar in the different deviations.

2.1.1 Reference

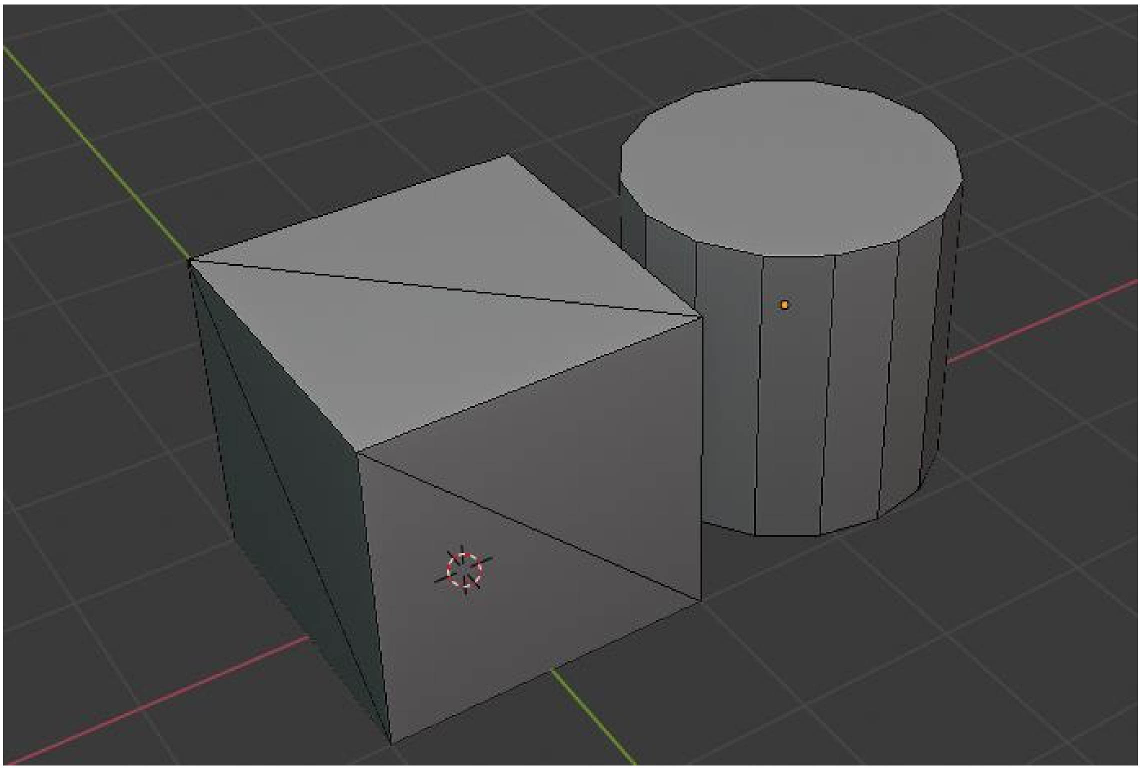
The first step in creating an 3D environment is gathering reference. Often into a sheet that the environment artist can source during the creation process (picture 1). This is an outline of different ideas and elements desired for the environment gathered on to a sheet as photographs. After iterating and searching for suitable reference the environment artist can move onto creating the 3D-models and textures for them. A general rule of thumb is to gather high quality images that have an adequate amount of variety (Corijn, dukes)



PICTURE 1. An example of reference material in the form of pictures I gathered for this thesis project. The reference material was gathered on to a reference sheet illustrating look and feel in the form of photographs.

2.1.2 3D modelling

3D modelling is the process of creating a representation of an object for viewing in three-dimensional form (Silverman 2013). 3D models are made of polygons that adhere to each other to create the surface of a model. Specialized softwares are used in the creation of 3d models by manipulating these polygons until the desired shape is achieved. The polygons are manipulated by moving or rotating them with tools provided by the software. A good starting point is to use a technique called box modelling. In this technique primitives such as cubes are used to mould the basic shape of the final model (picture 2). The basic shape is then used to sculpt out the final model.



PICTURE 2. Example of primitives in 3D modelling software which can be used as building blocks for larger more defined models.

There are certain rules that a 3D model must abide by to have it render properly inside the realtime engine. A model that has been created disregarding these rules often may show up broken in the realtime engine or have implications in the performance of the final product (Silverman 2013). It is the 3D artist's job to balance the rules and the visual fidelity and performance.

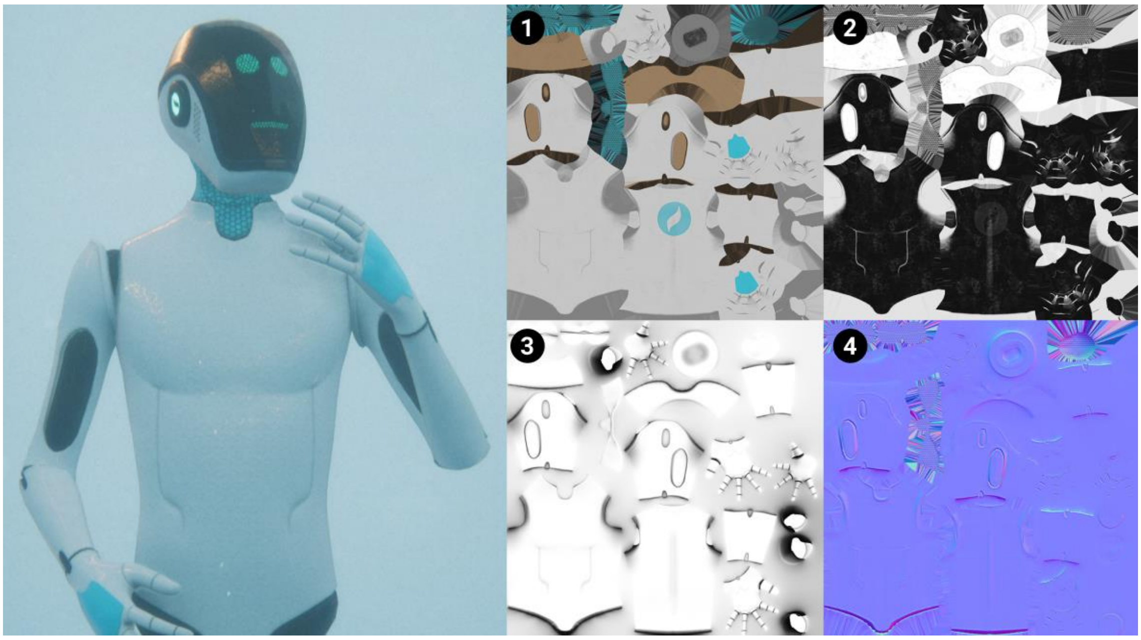
2.1.3 UV mapping

Once the desired form of a 3D model is achieved, the 3D artist begins the process of UV unwrapping. UV unwrapping is the process of unfolding the model's surface onto a 2D texture (picture 3). The polygons that define the geometry of the model are laid flat onto a plane like an unfolded paper model representing the model's surface. It is important to make the UV map cover the object uniformly to minimize texture stretching and other abnormalities in the surface of the model.

PICTURE 3. A 3D model (left) UV unwrapped on to an image texture plane (right).

Once the model has been UV unwrapped the 3D artist can begin the process of texturing the model on top of the created UV map. Texturing adds a new dimension to the 3D model and can make or break how your 3D model looks (Silverman 2013). Texture maps are applied on top of the 3D model surface to create an illustration of the surface details.

There are a lot of different texture maps used but I will be focusing on the basic texture maps used in a PBR pipeline, using an android model I created for illustrative purposes (picture 4). The PBR pipeline has been the result of long-term planning by graphics researchers since 1980's and was later developed to create photorealistic representations of textures (Pharr & Jakob & Humphreys, 2017). PBR tries to simulate accurate lighting models to render realistic materials and surfaces using a variety of different texture maps to represent different visual attributes of the material. The base of a basic PBR material consists of five different texture types: diffuse, metalness, ambient occlusion, roughness and normal maps.



PICTURE 4. Diffuse (1), Metallic/Roughness (2), AO (3) and Normal (4) texture maps and their rendered result in a realtime engine(left).

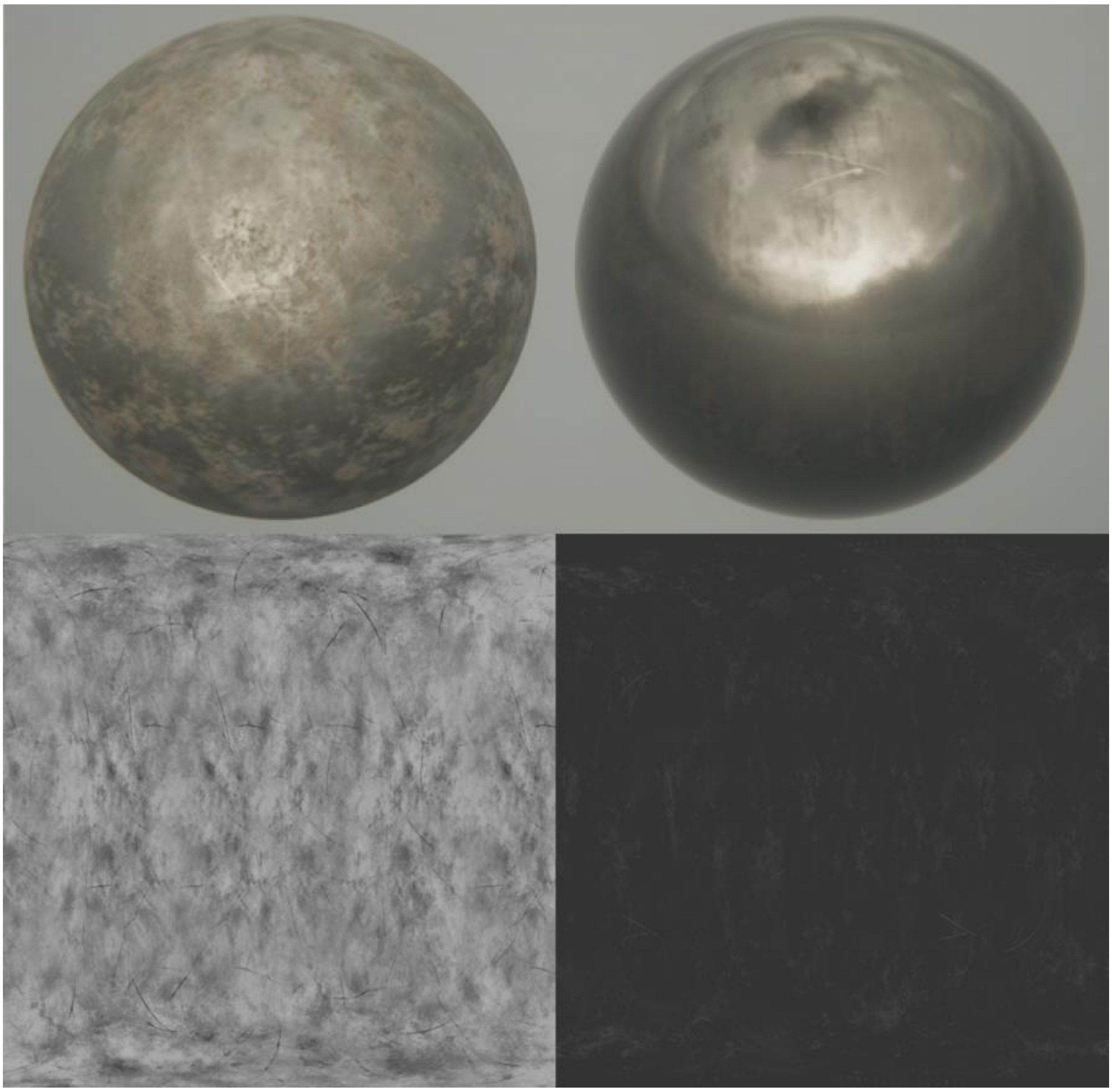
The diffuse texture map (picture 5) is the most basic texture map. The diffuse map is often referred to as the albedo and it defines the colour of diffused light (Wilson 2015). It doesn't contain any shading information, as this is reserved for the other maps. The diffuse map is often void of shadows and is somewhat flat in tonality when using PBR rendering.

PICTURE 5. Diffuse texture map consisting of colour details.

The metalness map is a greyscale map that indicates the degree of metallicity in the material. Non-metallic maps are called dielectric and metallic maps are called conductive, as they conduct electricity. The renderer perceives these materials with different reflective properties. When a pixel has the greyscale value of 1 or white it is metallic and 0 for dielectric. Most dielectric materials should vary from 0.04 and 0.1, and metallic are usually 1 (Nichols 2018). These values derive from real life measurements. Metallic maps are often combined with other maps to save on texture memory (picture 6).

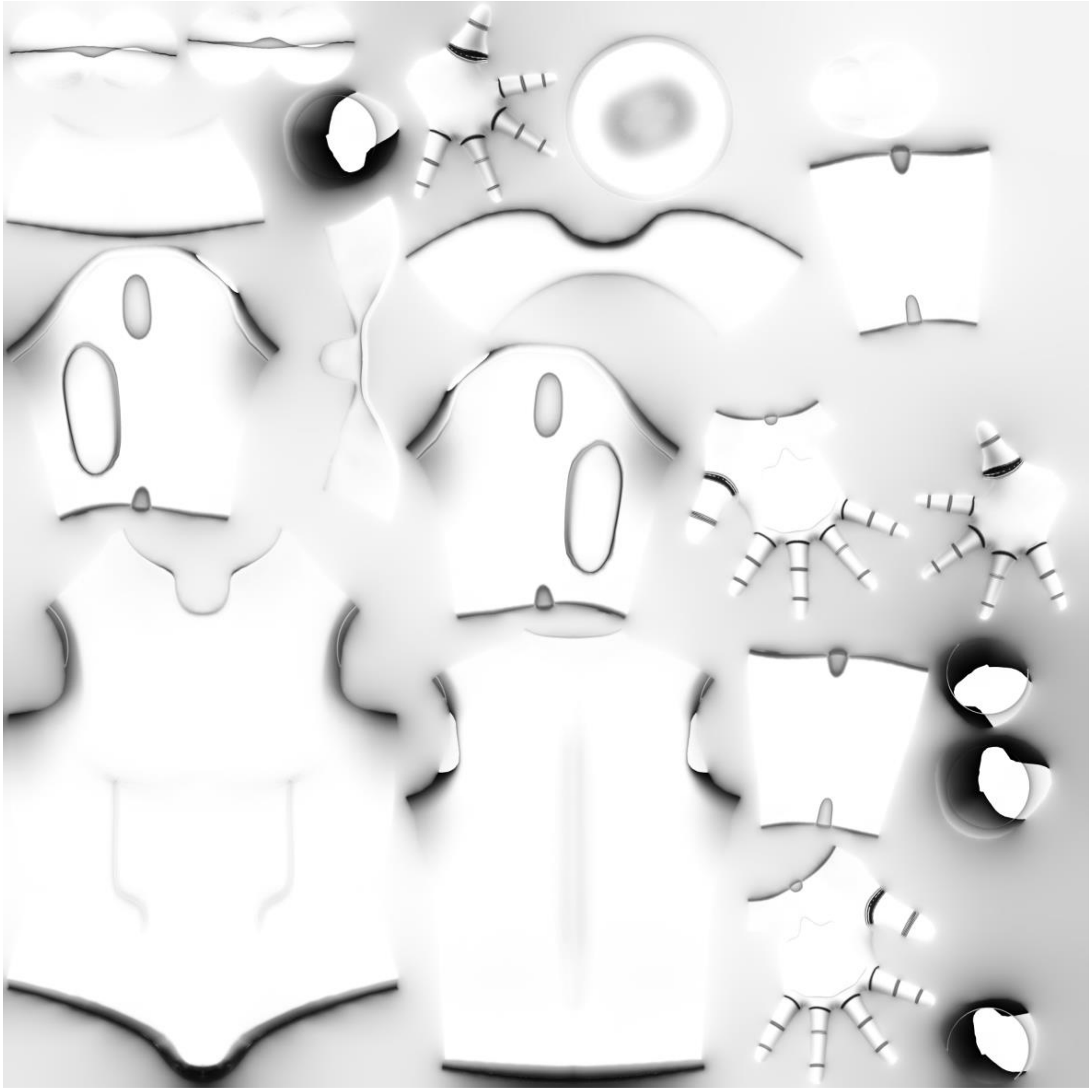
PICTURE 6. Metalness texture map combined with roughness map to save on texture memory.

A roughness map is a greyscale map that represents the surface irregularities that cause light diffusion (Wilson 2015). The roughness values change the light direction, but the light intensity remains the same. If the surface is rough the material will have larger and dimmer looking highlights and for smoother surfaces the reflections are more pronounced and focused. A value of black in the greyscale roughness map represents a smooth surface and white represents a rough surface. The roughness map allows for a lot of creativity as it allows the artist to define the condition of the model's surface (picture 7).



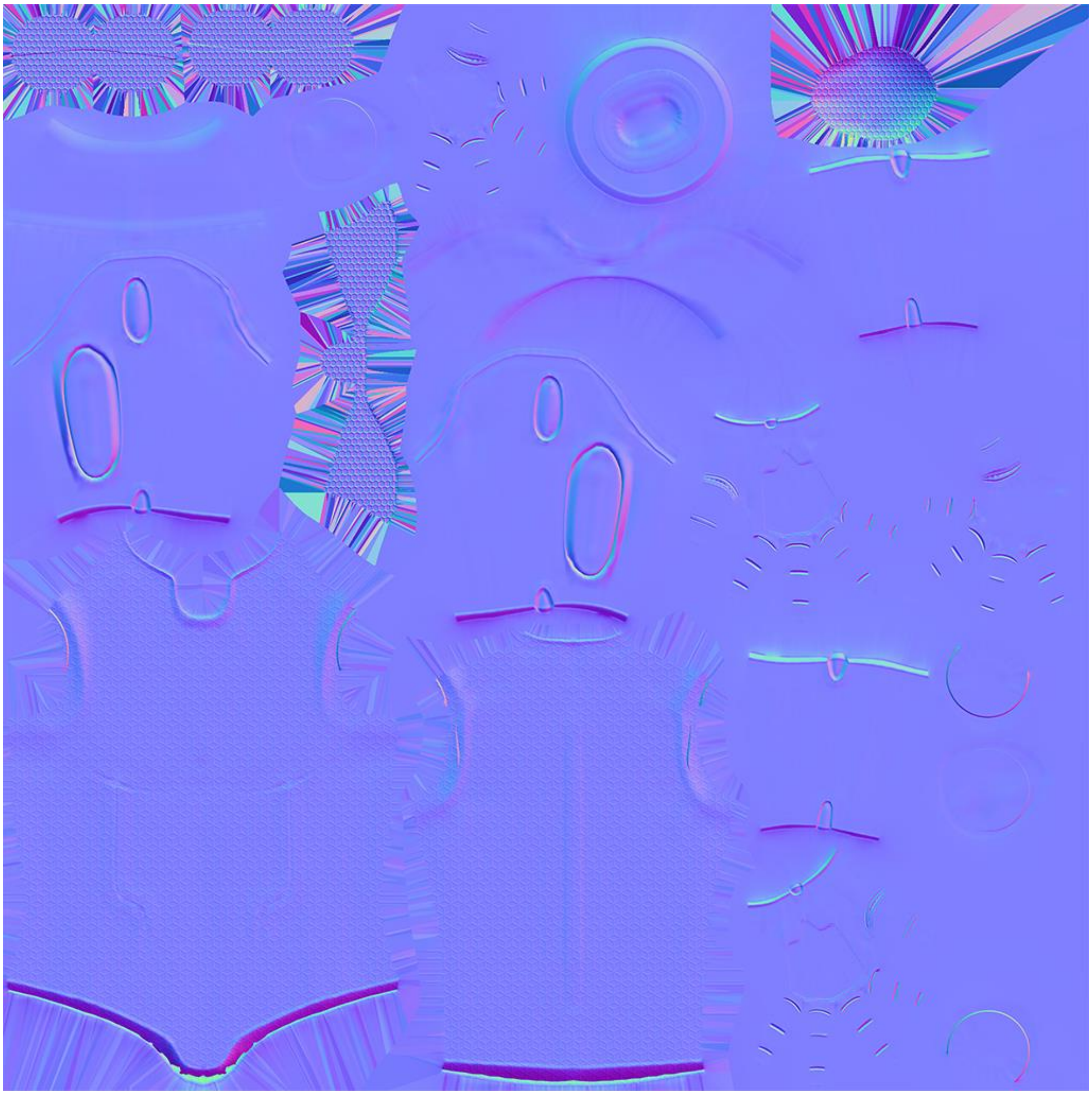
PICTURE 7. Two sphere 3D models with different roughness values. Higher values of roughness (left) give the model a grungier tone and lower values give a shinier surface (right).

The ambient occlusion texture map (picture 8) or AO map for short, is a greyscale map that represents diffuse light occlusion and is often baked from a 3D model (Wilson 2015). It defines how much of ambient environment lighting is accessible to different parts of the 3D-model. Giving the illusion of depth by adding darker areas in crevices for example. Often the AO maps are combined with the diffuse map, in engine by multiplying it on top of the diffuse map. Multiplying is a pixel colour mixing method which leads into darkening the value of pixels.



PICTURE 8. Ambient occlusion map. The different greyscale values of the pixels represent how much ambient light is on the surface.

The normal map (picture 9) is used to simulate surface details. It is in RGB map where each of the three colour channels correspond to a spatial dimension in tangent space. Tangent space is where normals are local to the surface triangle. These coordinate values are used to approximate the amount of light that reflects from the surface at a given point or pixel (McDermott 2018). This allows for the illusion of details on a relatively simple mesh.



PICTURE 9. Normal map texture. The RGB values of the pixels in the texture correspond to different spatial dimensions.

2.1.4 Baking

Traditional workflows make use of transferring details from a high poly model onto a low poly model (picture 10). The process involves a low poly model that is optimised for use in a Realtime engine. The baking tool will use this model as a shell and cast rays inwards onto another higher detail model (Trammel 2016). When the rays intersect the model, it records the surface details and saves that onto a texture map using the low poly models UV map. This enables the baking of normal and ambient occlusion details from a higher detail model onto a low poly model, saving on the rendering time and cost of the asset substantially.

The low poly model should be triangulated before baking, because the real time engine where it will be used will triangulate the model if it has not been triangulated and this can result in undesired outcomes. Modifying the low poly model's UV map after baking is not recommended and can result in abnormalities. The same baking workflow can be used to bake more advanced textures as well, such as curvature and thickness maps. These can be used to fake edge wear of materials or translucency.

PICTURE 10. Different stages of baking 3D model. Low poly model (top left) that defines the silhouette and the result of baking (lower left) with additional details. The final model (right) with the addition of diffuse texture map.

2.1.5 Workflow chart

These are the base steps incorporated in a traditional workflow (figure 1). Starting with the gathering of reference and blocking out the model in a modelling software. In the planning stage the model can be tested after the block out is done to get an idea on how the model sits in its environment. This helps to visualize any problems that might come up later. After the block out is done and meets the criteria set for the 3D model, we can move on to the high-resolution model that will later be used to bake details on to the low poly model. The high-resolution model can be optimized, by lowering the detail level to get the final game ready low poly model and after triangulation the high poly model can be baked on to the low poly model. This gives a good basis which we can texturize.

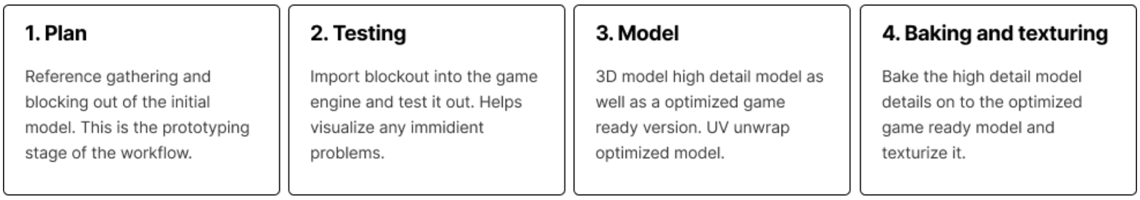


FIGURE 1. Basic steps of the traditional workflow.

2.1.6 Challenges of traditional workflow

The traditional workflow has its challenges, one of the major ones is the flexibility of the models themselves. After the model has been baked and textured, the look of the model is set and adjustments that can be made are minimal. Changing the model's geometry would break the UV maps created for it and this in turn would also break the baking and texturing side as well. The workflow would have to start from the beginning to have adjustments done. Although doing simple adjustments to the texturing can be done without starting over.

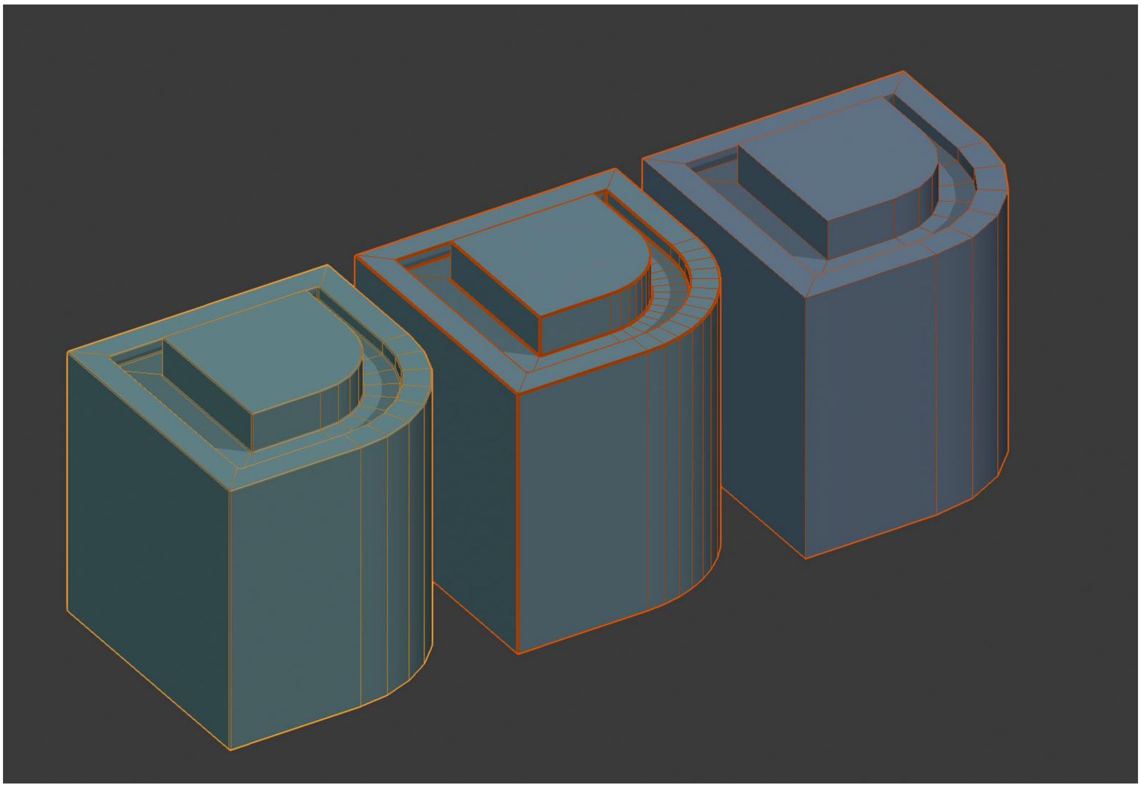
This means that working with a traditional workflow one must stand by the choices done in the beginning until the end of the model's lifecycle and adjustments done have large implications. The designing and reference gathering phase is of utmost importance in a traditional workflow as the model should not be at risk of too many revisions.

3 EMERGENCE OF MEDIUM POLY WORKFLOW WITH DECALS

3D environment creation being a combination of artistic prowess and the technical knowledge of the artist gives the chance to pursue their artistic freedom through the advancements in technology. Any given environment creation workflow in due time is achievable with less effort in the technical side as new workflows surface by the hand of sharing artists or companies in the industry. What took once months of work can now be done in a fraction of the time and often with the visual fidelity to compare.

The evolution of 3D environment creation is continuously evolving, as is also the expectations of the consumers. These technological advancements in new iterative workflows give the environment artist the tools to keep up with the incessant standards that the industry places for them. With these advancements studios can create assets in less time with an unprecedented amount of variety and modularity. This gives the artist and the studio a more streamlined and modular approach.

Medium poly workflow with decals is one of such advancements although it has its caveats. The workflow works as an enabler for the vision of studios and the vision of the artists. Enabling a modular way of thinking and straying away from the traditional way of thinking. With the modularity also comes the addition of detail and visual fidelity. The base of the medium poly workflow is the usage of medium poly meshes which are in between a high poly mesh and a low poly mesh. Giving the mesh enough detail to illustrate the form and smooth out the edges but leaving the micro details for the decals (picture 11).

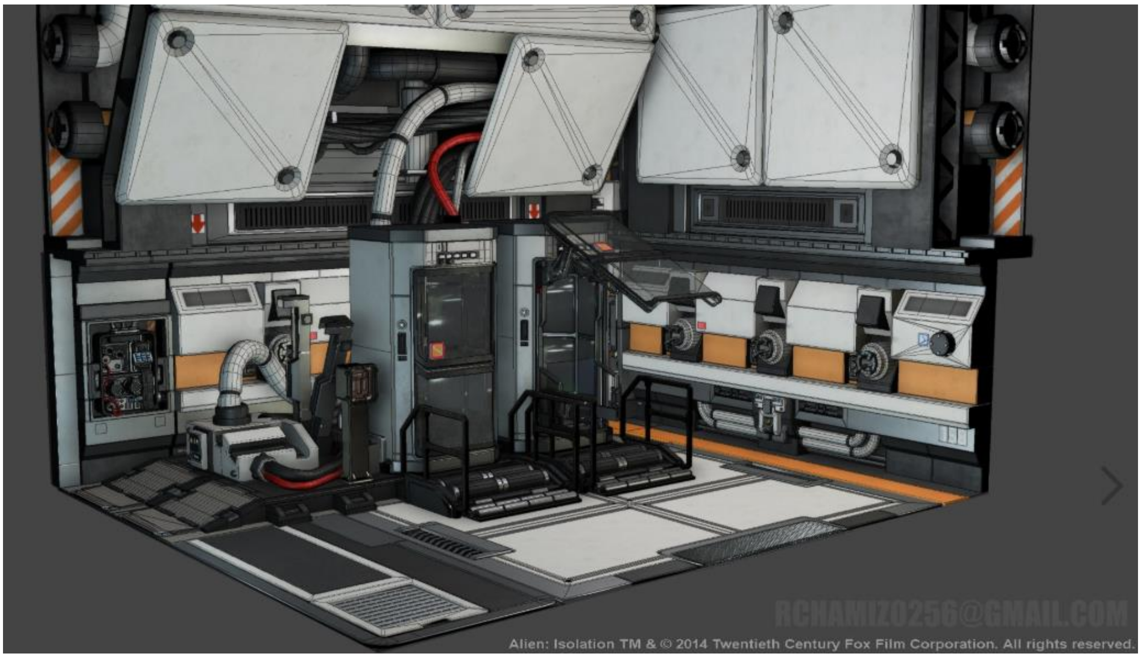


PICTURE 11. Different versions of the models lined up in blender. Medium poly (150 vertices), high poly (1000 vertices), and low poly (54 vertices) model.

3.1 Current visibility of the medium poly workflow in games

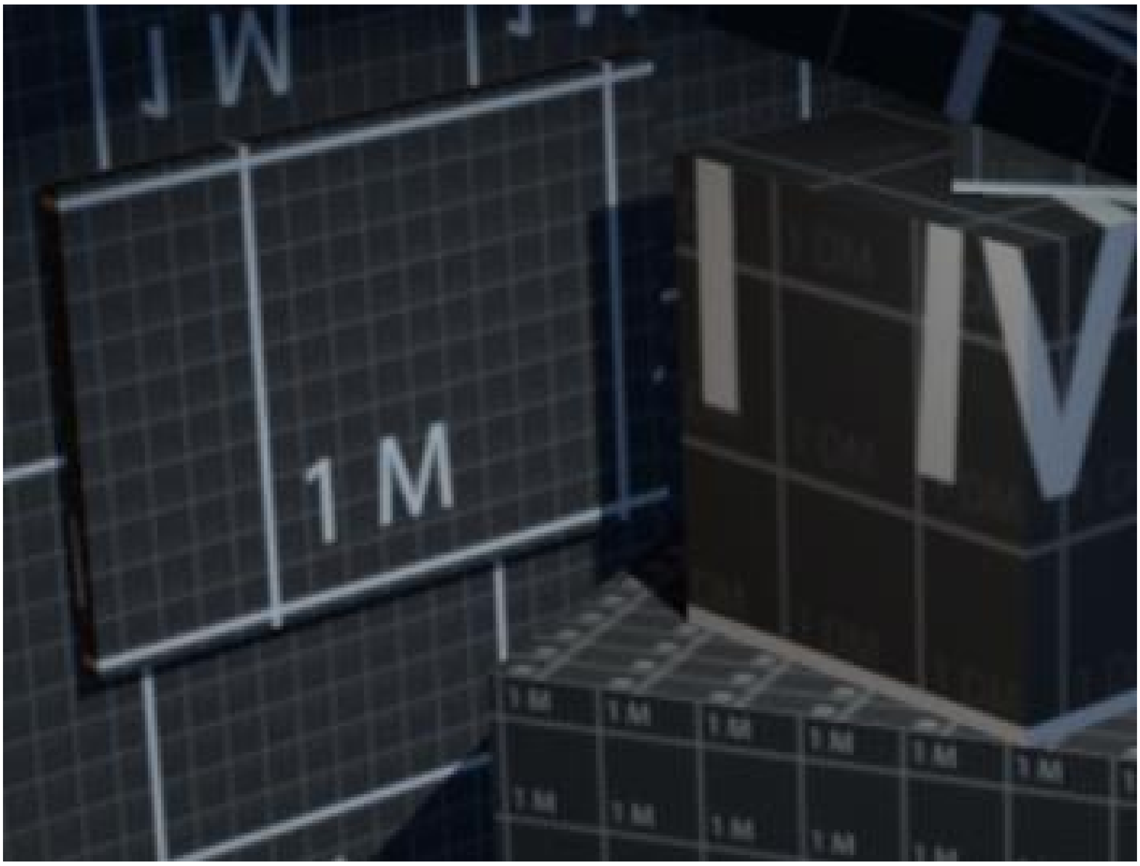
Before going into more detail on the medium poly workflow itself let us go through some of the visibility in the industry currently as I believe the visual fidelity of the workflow speaks for itself. The medium poly workflow with decals usage has been under the radar for some time but there is still a major showing in the triple A industry. Some well-known games that use this workflow are Alien: Isolation that was released in the winter of 2014 and a more recent game called Doom: Eternal. These games have used the workflow to its maximum potential for similar reasons.

Alien isolation was one of the earlier triple A games that used this workflow as during that development timeframe the optimisation of the assets was of paramount importance (picture 12). The usage of face weighted normals and medium poly models allowed them to create the environment they envisioned (Bailey 2015). The creation of the environment using traditional workflow would have had a major performance impact as the environment they wanted to achieve had a lot of detail.



PICTURE 12. Model created for Alien: Isolation by Ricardo Chamizo, using the medium poly workflow with decals. (Chamizo 2015)

Texel density is the amount of texture resolution on a mesh. Having the correct texel density between your models is paramount in achieving a consistent quality in your environments (picture 13) (Lezzi 2017). When the texel density of models is inconsistent it creates disbelief as one object can be crisp and clean and the other next to it might have blurry textures. Choosing the right model scale, texture sizes and texel density to use in the art assets is important in the start of environment creation workflow, otherwise the models will not look proportional.



PICTURE 13. The grid illustrates the tiling of textures on the models. Incorrect texel density is visible as the tiling is too varied compared to other models (Lezzi 2017)

In first person games, having a texel density that enables close examination of models maintains a level of immersion. During the development of the engine for Alien: Isolation they wanted to maintain a detail level where the player could examine and read labels on 3D models (picture 14) (Bailey 2015). Using the medium poly workflow with decals this is possible as the detail level for models is increased drastically while keeping the performance impact at minimal levels.

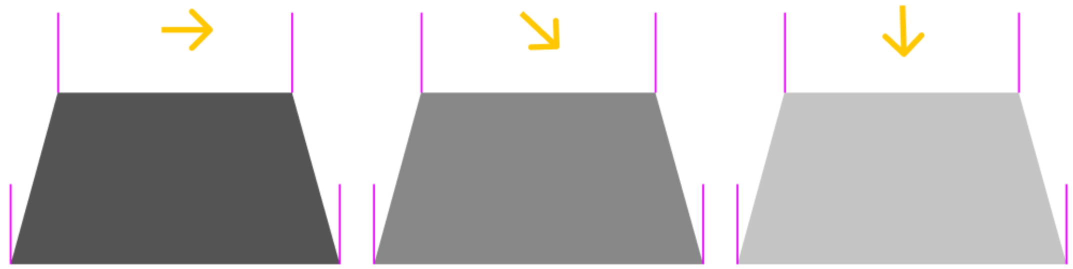
PICTURE 14. The level of detail is kept at a level where the player can examine the notes and read them.

A more recent example using the medium poly workflow with decals is Doom: Eternal. Doom: Eternal uses their proprietary game engine called id Tech 7 for which they have developed several technical advancements that allow the artist to place decals on the surface of objects to add detail on models (picture 15). These decals can be moved around allowing increased speed and efficiency during the modelling process.

PICTURE 15. The addition of decals adds a lot of detail to the models (right). The asset without decals looks bland (left) (digital foundry 2020).

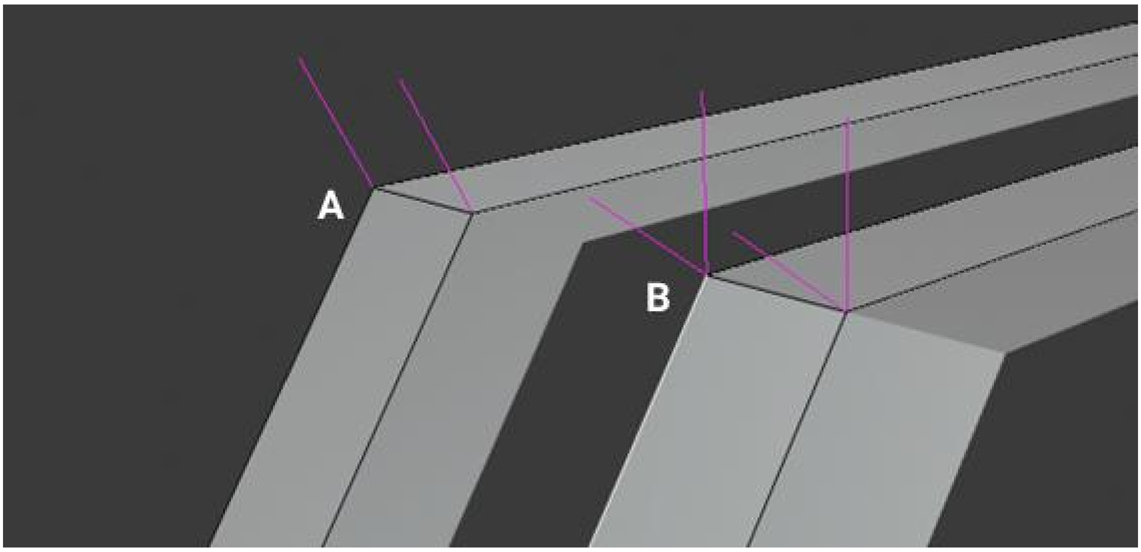
3.2 Modelling medium poly

The workflow is derived from using the 3d model's vertex normal directions to manipulate the visual presentation of light bouncing off the surface of the model. A normal direction vector is used to calculate the way light bounces off the face of a model. A vertex is the smallest building block of a 3D model and two vertices that are connected are called edges. When connecting three or more edges together you are left with a face. Each one of the vertices have a normal direction vector. These vectors have an angle that determines how much lighting affects it and the direction (picture 16).



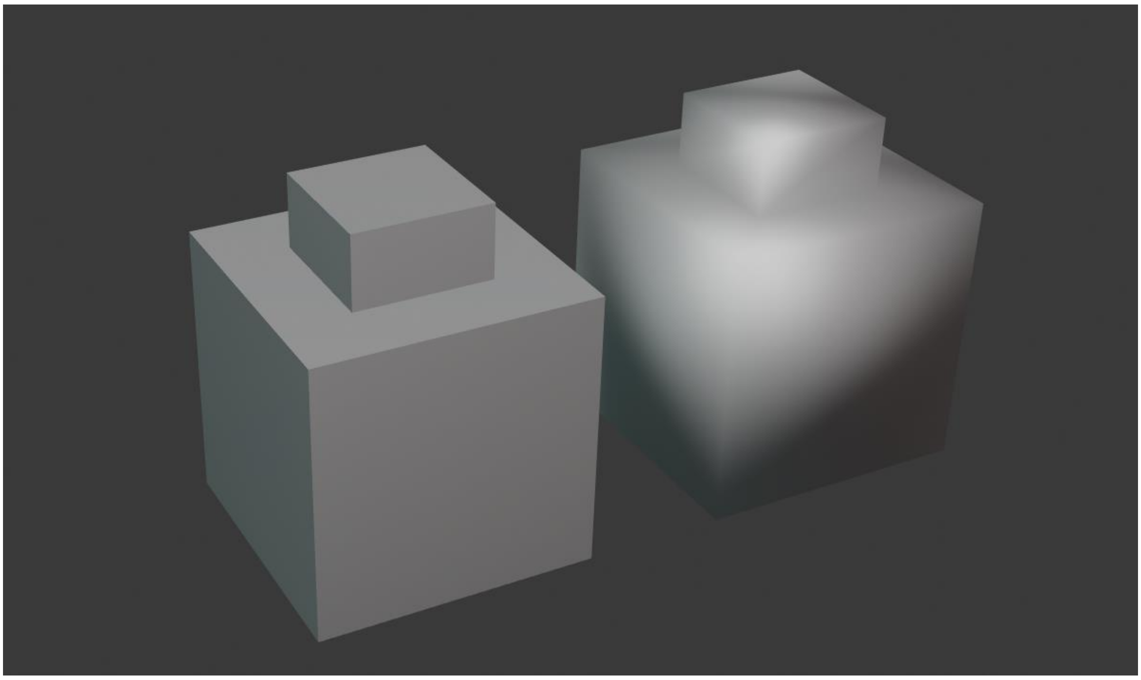
PICTURE 16. Illustration of how lighting direction affects the polygon face when the vertex normal direction is kept untouched. Arrow illustrates the direction of lighting and the different brightness values of grey illustrate the influence of light.

These normal direction vectors are also used to determine the smoothness of an edge (picture 17). Manipulation of these vectors give you the freedom of giving the object the appearance of being one unified surface. Having smooth edges is often referred to as smooth shading and is the opposite of flat shading with hard edges.



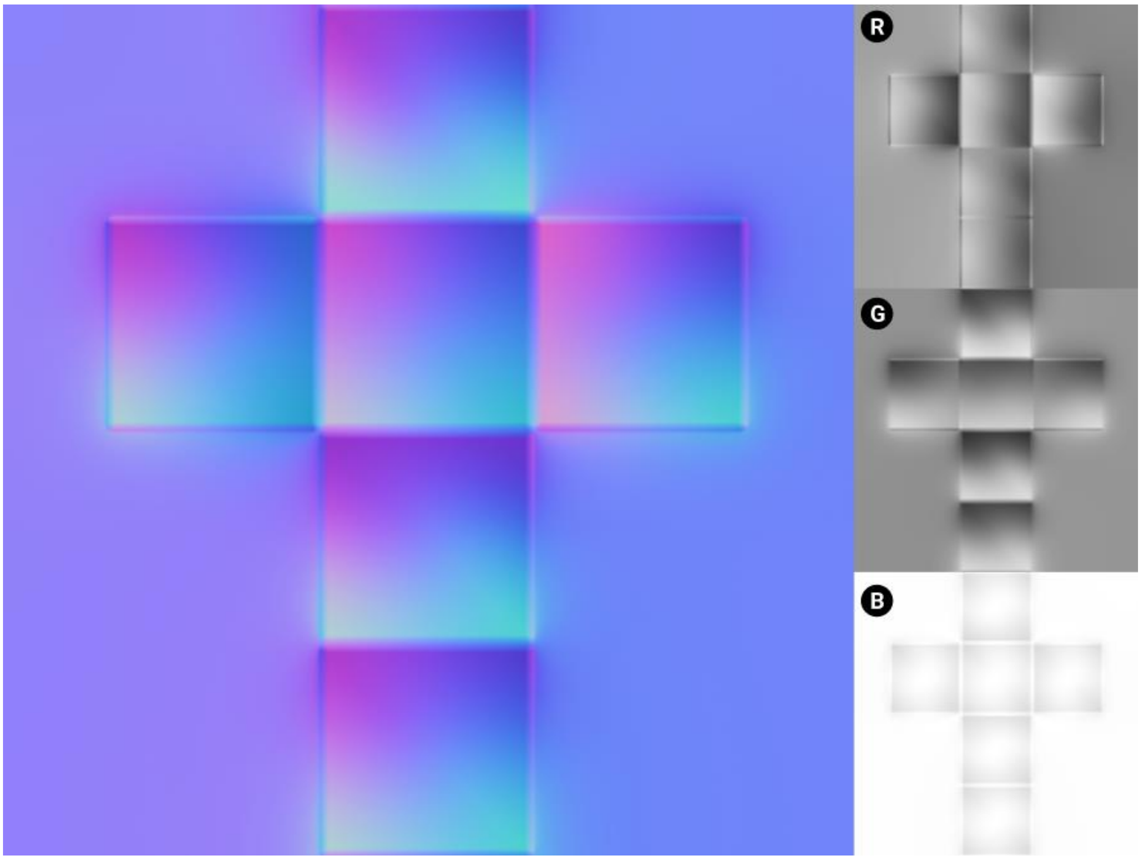
PICTURE 17. If the angle of light is the same for the edge connecting two faces the lighting will bounce off smoothly (A), but if the vectors point different directions the light will also bounce to different directions making the edge appear hard (B).

Using smooth shading gives objects a smoother appearance, but also as it smoothens the edges it creates unwanted abnormalities in the model's surface because the normal direction vectors are used as sum of the lighting direction (picture 18) (Vesterinen 2016).

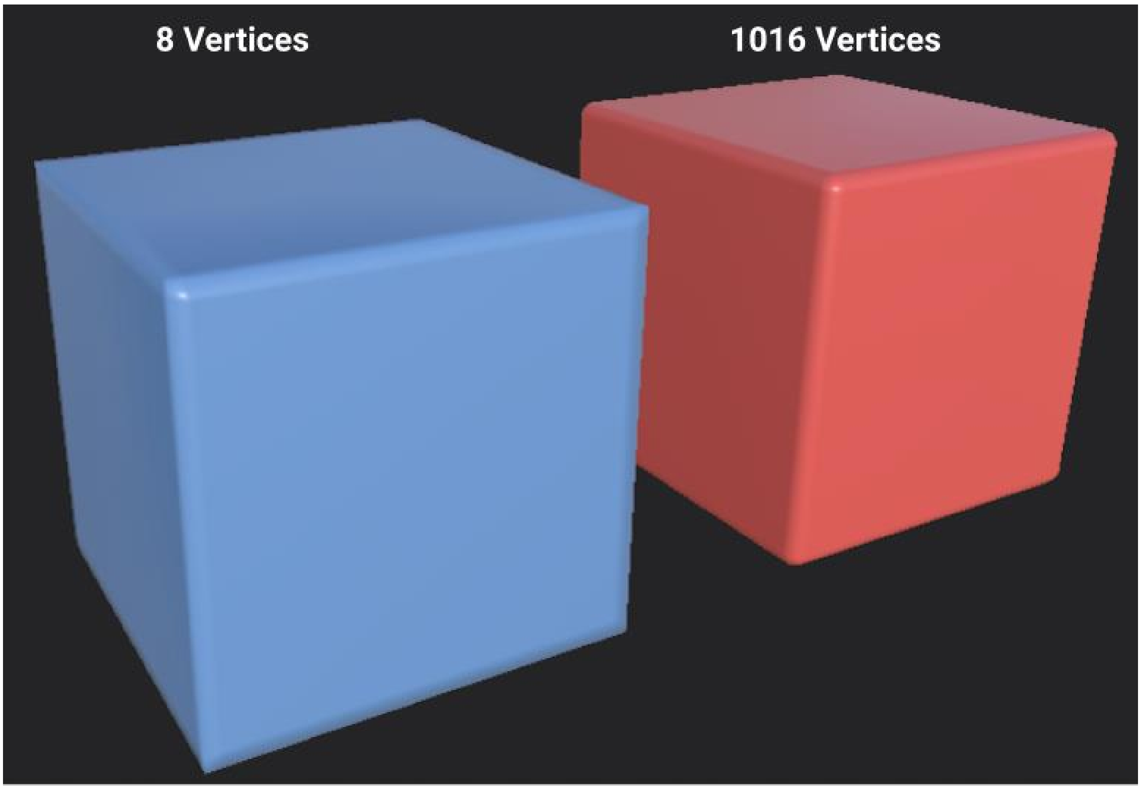


PICTURE 18. Flat shaded model with defined characteristics (left) and a smooth shaded model with surface abnormalities (right).

The hard edges of a flat shaded model look unnatural even though the shading is correct and in turn the smooth shaded model has lost most of the model's definition. Normal maps are used to store the normal direction per pixel and requires the use of a UV-mapped mesh. Normal maps store data in the RGB channels of the texture map. These channels point a certain direction based on the axis that is stored in the channel (picture 19). This is commonly used to fake high-resolution detail on models as well as giving the models the appearance of smoother edges although the models actual definition is using hard edges (picture 20).



PICTURE 19. Normal map (left) with all color channels illustrated (right). The red channel stores the 'X' dimension, the green channel stores the 'Y' dimension and the blue channel stores the 'Z' dimension.

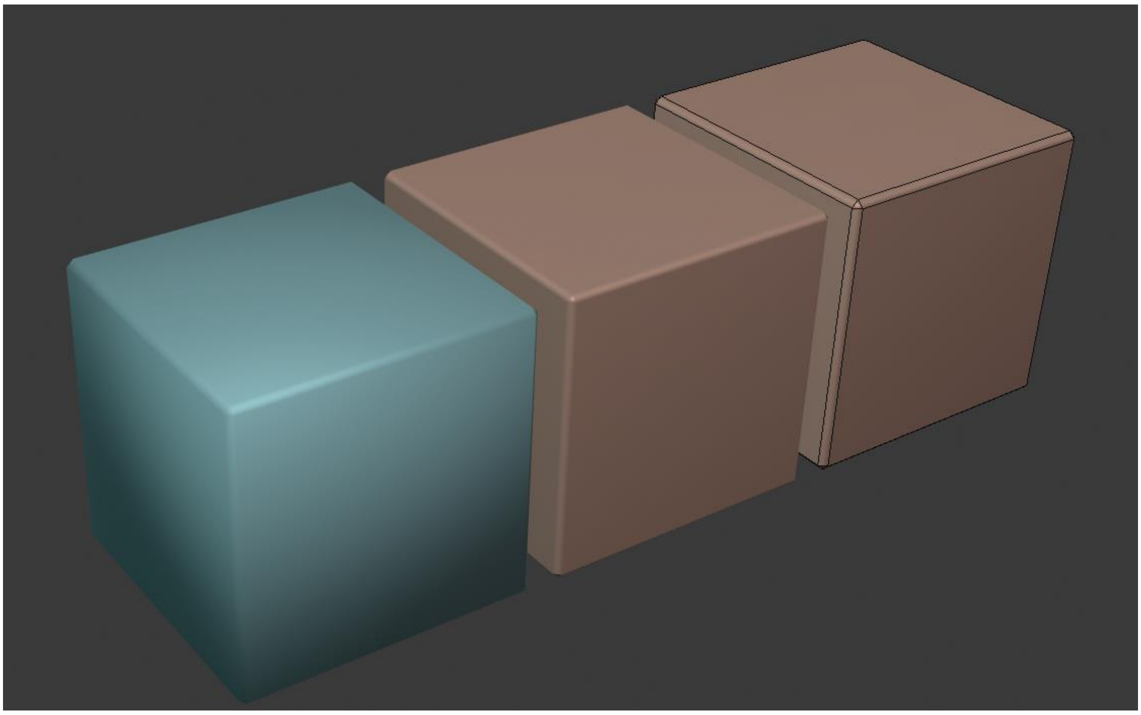


PICTURE 20. A high poly version (right) of the model is used to bake the normals for the low poly model to give the appearance of smooth edges but have a hard silhouette (left).

Using normal maps has the caveat of requiring a unique normal map and as such the quality of the detail is tied to the resolution of the normal map texture. With larger models, baking a high poly mesh on to a low poly mesh requires high resolution texture to give an adequate amount of detail. This can cause issues considering memory usage and rendering performance. The workflow can be time consuming as going through the traditional steps of modeling two versions of the model and baking them locks the model into that certain look unless redone. This is also prone to a lot of visual errors as the details are tied to a texture bake that must work out perfectly to get out the level of polish needed for a quality model. Some errors that often plague baked models are tangent space errors, normal errors and errors with compression (Vesterinen 2016). In the medium poly workflow, the idea is to get away with not using model wide normal map textures at all and instead use the polygonal detail level to smoothen the hard edges, this is where weighted normal come in.

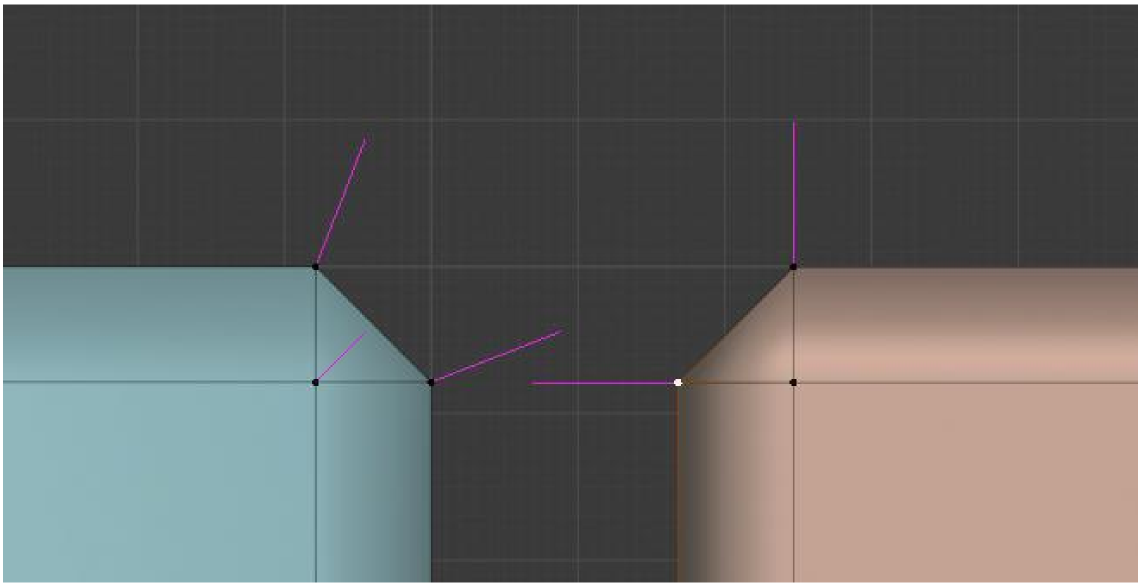
3.2.1 Weighted normals

As the processing power has grown in the recent years it has given us the chance to allocate the power to increase the polygon amount instead of using the memory to save all the texture data. Increasing the polygon amount enables us to add chamfers to the edges of models giving them a smoother appearance. Although this gives the model a silhouette that further matches with the high poly model, the normal direction vectors create anomalies on the surface of the model (picture 21).



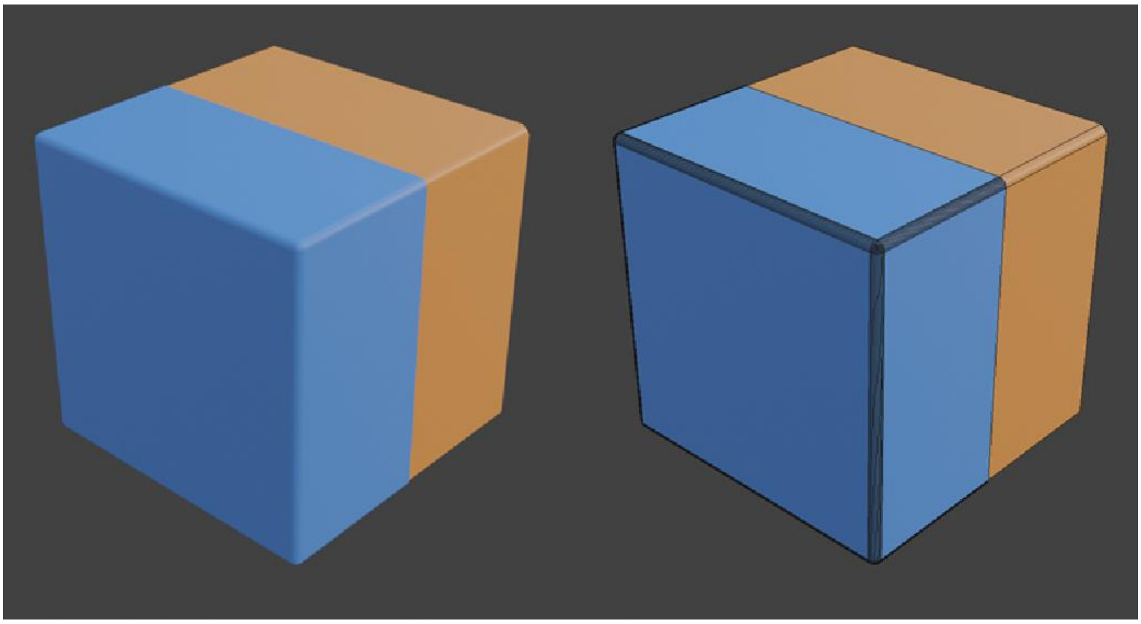
PICTURE 21. Chamfering the edges gives the model a more suitable silhouette (left) but requires normal adjustments (middle). The detail level after chamfering the edges (right).

To alleviate the distorted normals we need to adjust the normal direction vectors so that they are aligned in a way that each surface has defined shading that is more appropriate. To do this every normal direction vector connected to a clean shaded quad should be perpendicular to the surface, this way the surface will have clean shading, and this gives the adjacent chamfers the appearance of a smooth edge. Different values of adjustment are needed to get the most out of different shapes and chamfers (picture 22).



PICTURE 22. Default vertex normal direction (left) compared with face weighted normals (right).

Adjusting the normal direction vectors by hand is a hassle so this is where face weighted normals come in. Weighted normals come from weighting the normal direction vector depending on the surface area (Buijs 2007). Larger areas of surface have a larger weighting and thus they get a flatter shading and smaller areas have smaller weighting and so they have smaller influence on the normal direction vectors. These weighted normals can be achieved in numerous ways in different software’s. The technique I have come accustomed to is using a modifier in blender called weighted normal modifier. This modifier lets you adjust the weighting values precisely. Generally using this technique gives superior shading in most cases (picture 23).



PICTURE 23. Comparison of high poly model (blue) and face weighted model (orange) in an intersection. The models are almost identical although the detail level used is distinct (right).

3.2.2 Absence of normal textures and the benefits

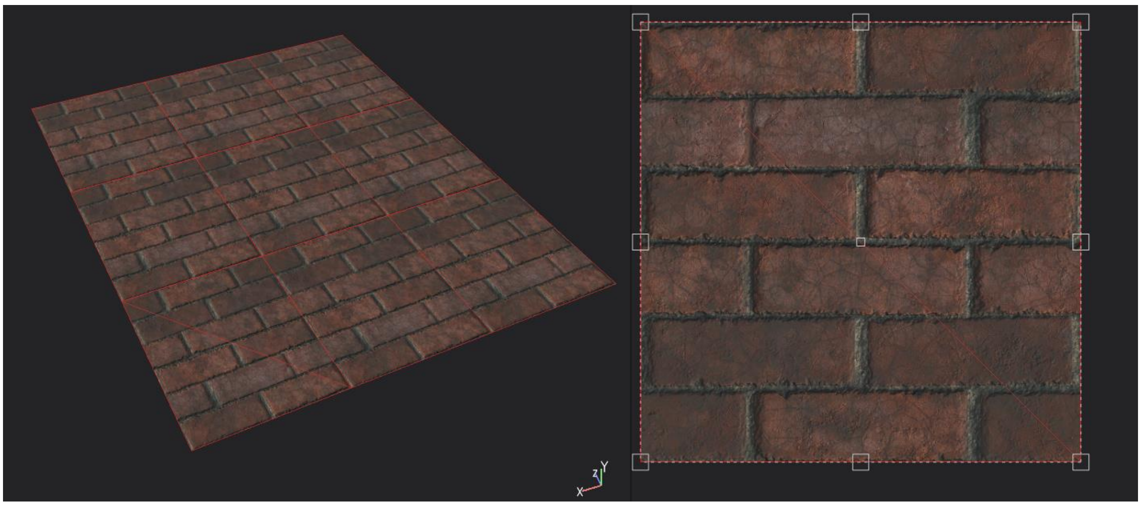
The usage of face weighted normals on a model alleviates the need for baking normals, although normals can still be baked if needed for example for a large 3D model to lessen the number of gradient anomalies on the surface of the model. This also gives the 3D artist the ability to see the detail level as it is while modelling, instead of having to go through the baking process. Giving a faster turnaround in the creation process of a model. From a workflow perspective this is highly beneficial as the artist can continuously reiterate on the model and the model's details are not set in stone like in the traditional workflow. In the traditional workflow, once the details have been baked the iteration process in that sense stops as any changes made must go through the baking process again.

When using normal textures, the resolution of the texture determines the level of detail and when creating a large set piece for example the resolution of the model needs to be very high for the details to be at adequate level. With weighted normals the need for baking edges for models is removed and thus the larger models can have smooth "high poly" level edges, without the need of normal textures (picture 24) (Vesterinen 2016).

PICTURE 24. Large ship model from the game “Star Citizen” utilizes the medium poly workflow to achieve high level of detail without baking unique normal textures (Brown 2015).

3.2.3 Tileable materials

Tileable materials are materials that use seamless textures. Seamless textures are images that can be placed next to each other on any side without any obvious seams, joins or boundaries between them (picture 25) (Povey). Tileable materials can be used in numerous ways as they are often not bound to a singular model and they can be modified to create variations (Silverman 2013).



PICTURE 25. Seamless texture tiled onto a plane nine times.

When the need to bake actual materials for every mesh is removed, we are given the chance to use highly detailed tiling materials. Tiling materials come into their own when the detail level rises for models as tileable materials can be lower resolution but tiling them gives the appearance of detail. Tileable materials also give the opportunity to re-use materials in a variety of models as they are not tied to the models unique UV map. This allows one to create a material library and switch the materials on the fly without modifying the underlying model and creating multiple variations just based on the material itself (picture 26).

PICTURE 26. Duplicate of the same wall model with different tiling materials. Using different materials for the same model changes the appearance of the model drastically. The variation only requires changing the materials.

Keeping the texel density uniform is easier when using tileable materials, although the models still need to be scaled correctly as this makes using the correct tiling values easier. There are ways to go around this by using texture tiling tied to the world scale. This makes the textures tile based on the world position coordinates instead of the object position coordinates and enables you to have the same texel density on every model, but this technique is prone to using more resources and requires adjustments to the material shader.

In the medium poly workflow with decals the texel density of models rises to new heights. As the absence of baking enables us to use tiling materials on all models, which enables us to raise it to the level that is the most visually attractive. The details being tied to decals that use the same texel density as the surrounding model by using a calculated atlas texture. Although you will need to keep the size of the decals uniform or the texel density will suffer.

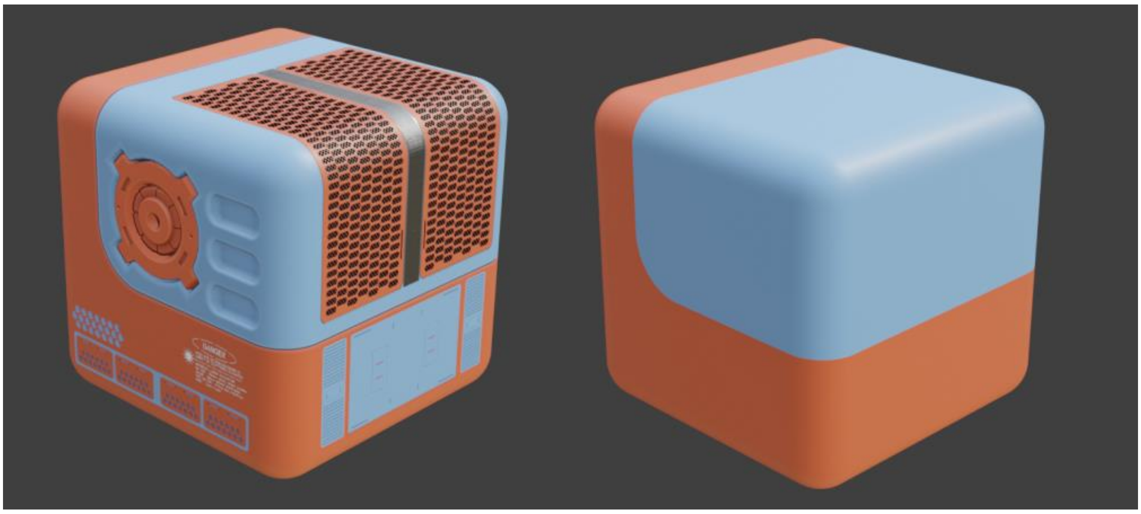
I believe that one caveat for using tileable materials is that one is left with a model that doesn't usually have baked information and adding detail like dust in crevices or corner abrasion is made more difficult. In the traditional workflow using baked information of a model enables you to create materials that showcase levels of wear and tear, but often means using tileable materials are a no go except when taking advantage of smart materials. Smart materials are designed materials that have variable properties based on baked information from the 3D-model. This baked information comes in the form of texture maps that can be used to add additional information on to the model or masking different areas of the model to use different seamless textures or material properties. Smart materials enable the use of baked information in conjunction with tileable materials, although this requires you to create shaders for that purpose. This technique of masking material properties on to a model is another way of dealing with the same end results as the topic of the thesis, usage of decals to add detail. As decals can be used to add detail such as dust or corner abrasions but have a multitude of other uses as well.

3.3 Addition of mesh decals

A medium polygon model with tileable materials can look bland as the details come only from the geometry of the object, no baking is done. One way to add detail onto the objects are decals. Decals are derived from assets that consist of a single face or otherwise very simple geometry and are projected onto a surface to add detail (picture 27). At the most basic level decals can be splatters of image textures added on top of surfaces such as posters on a wall to obfuscate any repetitiveness (Silverman 2013). These decals can use the same material properties as any other physically based material and as such they can use transparency to indicate features, such as bullet holes or different values of roughness to indicate features, such as surface wetness. They can also be used to add dirt on to the lower part of a wall or emissive details such as strips of light.

PICTURE 27. A variety of details added onto the environment using a combination of decals (Substance Source 2020).

In the medium poly workflow, decals are used to add in all the finer details as the medium poly model takes care of the edges and larger silhouette. As decals can take advantage of different PBR maps they can also use normal maps. Normal maps give the appearance of geometry and this can be used to add details to the otherwise bland medium poly model (picture 28).



PICTURE 28. Decals can bring a lot of detail (left) to an otherwise bland 3D model (right).

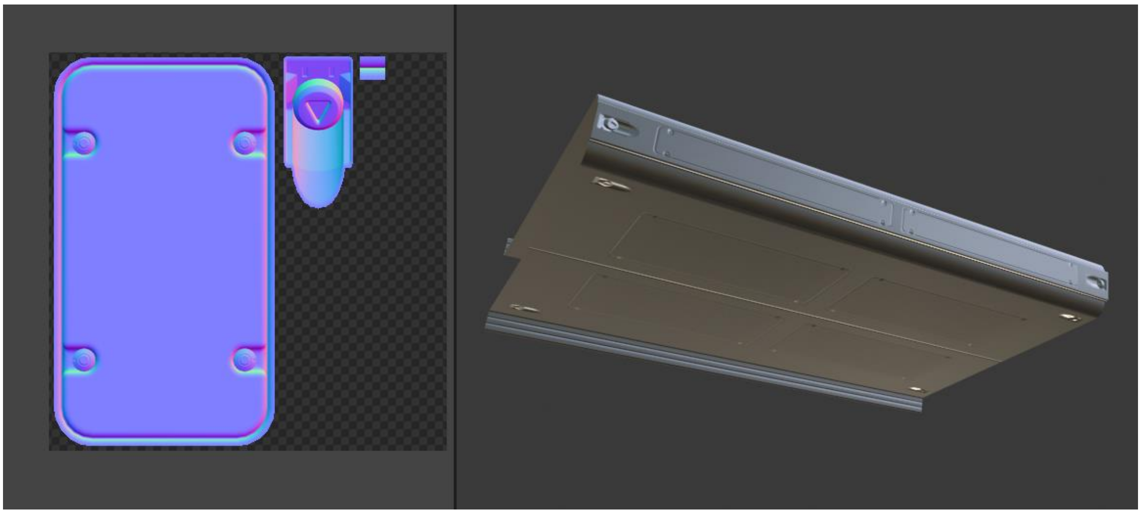
Decals also enable us to add details at any part of the workflow. As they are usually pieces of textures that are laid on top of the mesh. They can be added or customized at any stage of the modelling workflow although they are often added in at the modelling stage to have precise placement. Decals that are added to the model as simple geometry are called mesh decals as they are created as part of the model although they are a separate mesh. A variety of textures are used on the decal geometry to add detail such as rivets, panels or other micro details (Vesterinen 2016). When using these in conjunction with tileable materials you get incredibly high quality and non-destructive detail on you models with low resource usage.

3.3.1 Texture Atlas

When using a vast number of decals, a way to reuse the same textures is needed to cut down on the amount of materials and textures and this is where texture atlases come to play. Using texture atlases is a technique where the 3D artist combines a variety of textures onto a single texture map (picture 29) (Ivanov 2006). This is an old technique derived from having performance limitations as it is often more efficient to store textures in a single file reducing the overhead between texture maps.

PICTURE 29. The models in the scene are all mapped on to a single image texture. (Ivanov 2006)

This same technique is used in modern workflows such as this medium poly workflow with decals (picture 30). The number of decals that are used to add details grows exponentially and a lot of details are re used such as screw holes and such. This technique gives the modeler the opportunity to have all these details baked on to a single texture with a small memory footprint and from this atlas of decals one can then copy details all around the model. In theory a single detail texture atlas map can be used for a whole environment.



PICTURE 30. All decal details are baked on to a small image texture (left) even though the decals are used multiple times on the model (right).

3.4 Expected benefits of medium poly workflow with decals

I believe the workflow enables the user to have an unprecedented versatility in the creation process by using weighted normals that help removing the need to bake one off model and create unique textures for each model. This in turn helps the production in having a unified workflow as there aren't a variety of different models to work with. This also enables a non-destructive workflow by enabling iteration at different levels of the workflow. Modification of details can be done at any stage of the workflow and materials can change the visual appearance of the model at even the latest stages because the models are not locked into a stage.

It seems that the versatility of the workflow helps the production save time in different aspects of the model creation process. One of such situations is the creation of variations as the models can be iterated on at different stages by changing the placement of decals or adding in new details in decal form when the model is already in the realtime engine as well as modifying the colours and materials at any stage in the workflow.

The planning stage in the workflow is very important as the creation of the meshes for the models takes time and alleviating any need for creating additional meshes saves time as well as keeps the texel density in check. Having a consistent high quality texel density by using decals and tileable materials gives crispier details on larger assets. The usage of tileable materials and atlas textures for decals also lessens the strain on the memory bandwidth.

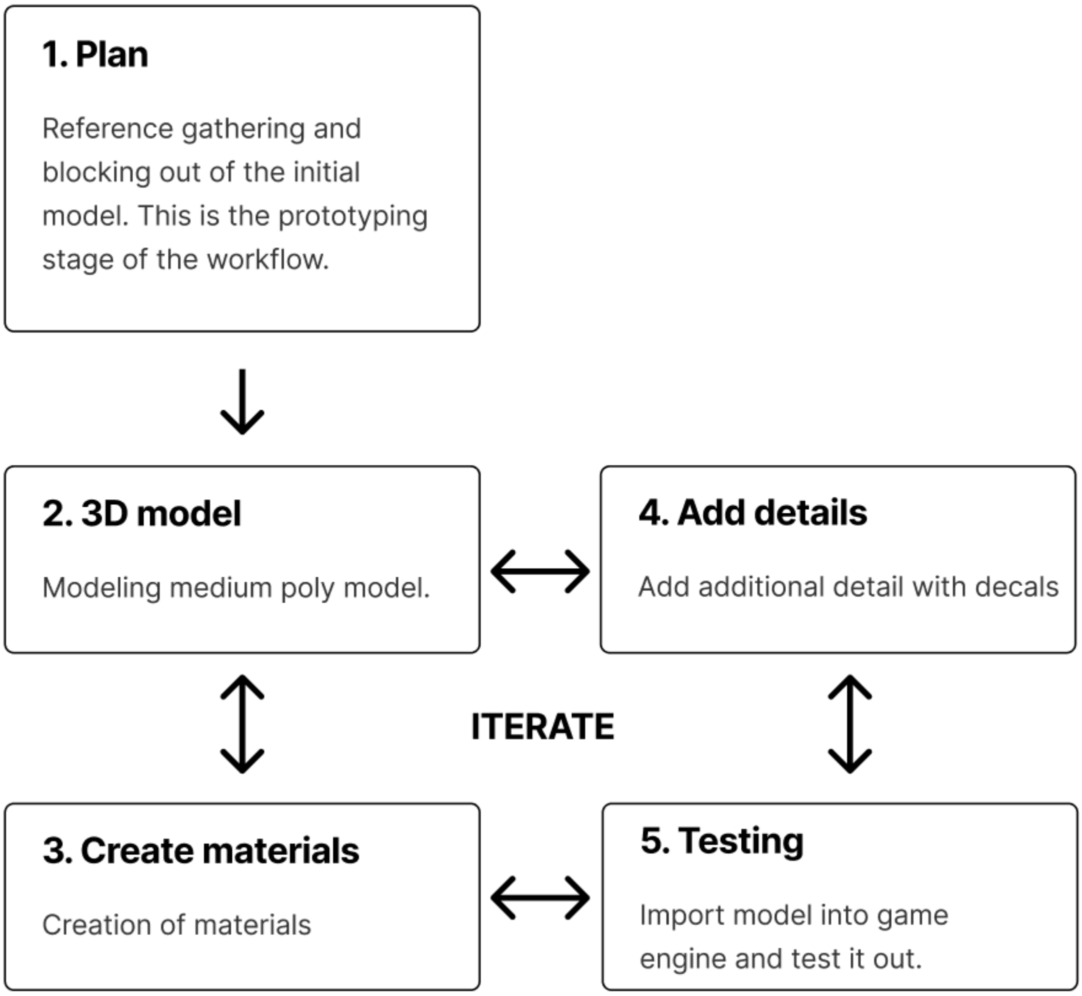


FIGURE 2. The workflow for creating assets is flexible and allows for iteration at every stage of the workflow, going back to different stages non-destructively.

Some drawbacks or cons for the workflow are that the LODs or level of detail meshes of the models need to be created carefully and planned ahead in time because of the chamfers or bevels that are added to the models and because there isn’t any baking involved in this workflow. The increased polygon amount does have a performance impact as there will be a lot more polygon faces as a result of the bevels, but this is balanced out as the memory imprint is a lot smaller compared to the traditional workflow.

4 MEDIUM POLY WORKFLOW IN ACTION

4.1 Goals and scope

The goal of this workflow test is to create a compact interior 3d environment using medium poly workflow with the addition of decals for the details and also creating some elements from the environment using the traditional baking workflow. This will then provide insight into the benefits of each and let me compare each workflow in the environment creation process from a performative technical-, graphical fidelity- and flexibility standpoint.

The practical output is creating a suitable interior for the comparison and presenting it inside a real time engine. During the creation I will be researching the workflow further and the tools used for the implementation. I expect the results to demonstrate the workflows by themselves in a readable way.

The theme for the project was chosen based on the usage of the workflow in the game industry, as most projects using this workflow have sci-fi themes and I believe the themes architecture works well with the workflow as hard surface models are prone to have normal baking issues.

4.2 Planning and blockout

Every 3D project should begin from the planning stage and so did this one. My plan was to create something that inspired me. At the moment I was intrigued by tiny houses and compact living and wanted to incorporate that into this project with a unique twist. The project began by finding reference images of tiny houses and different kinds of architecture that had these elements and had some sci-fi influence (picture 31; picture 32). So, the idea was narrowed down to a compact living space in the future.

PICTURE 31. Aesthetics of the capsule tower located in Nagasaki.

PICTURE 32. The compact interior of an apartment in the capsule tower in Nagasaki.

It was important to keep the project small due to knowing that the assets needed to be created multiple times to have a clear understanding of the workflow at hand and help the comparative study. Creating a small living space gave me the possibility to create a mixture of modular and unique assets as these compact architectural interiors often have a lot of unique surfaces. The projects goal was to create a dexterous interior that was compact and had a sense of space even though being confined.

The next step after locking in the scope and interior type was to begin planning the aesthetical side. I did not want to duplicate any existing interior and wanted to bring the environment into a science fiction setting. Knowing that the materials would affect the aesthetics of the interior a lot, concentrating on them before moving onwards in the project was a great starting point. The main material choice of different kinds of plastic was inspired by the works of Lepik Daniel (picture 33). He has used different kinds of plastic materials successfully with unique shapes and roughness variations that are aesthetically pleasing. The choice to use wood as the secondary material came from the desire to create contrast between the plastic materials and give a more earthy tone.

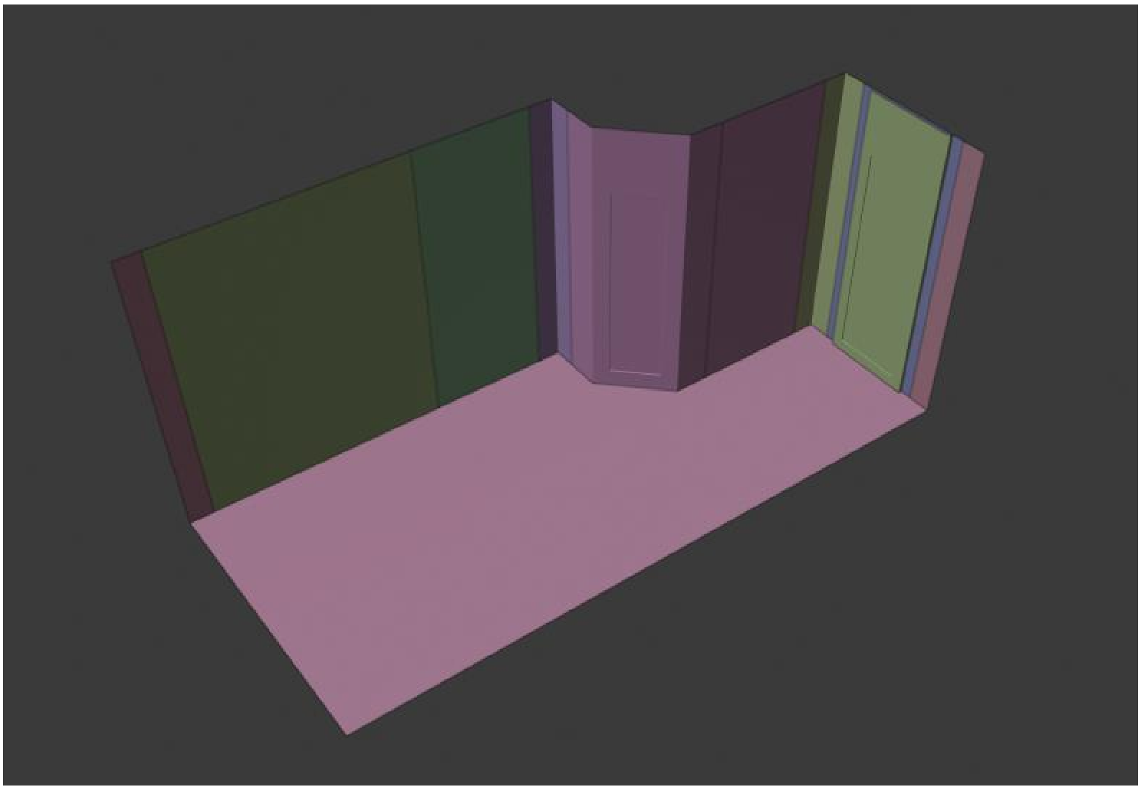
PICTURE 33. Works of Lepik Daniel gathered into a reference sheet.

Decals would be used to add variety of detail such as screws and panels to the medium poly models (picture 34). The idea is to add all micro details through the usage of decals in the medium poly workflow and bake the same details on to the models in the traditional workflow to enable a level comparison of both workflows.

PICTURE 34. A reference sheet I created to illustrate the theme of the environment and details added through decals.

My plan for the lighting was to emulate as much natural light as possible in the environment by adding a large window centrepiece, using small lights to supplement the natural light and create a contrast with warm and cold light.

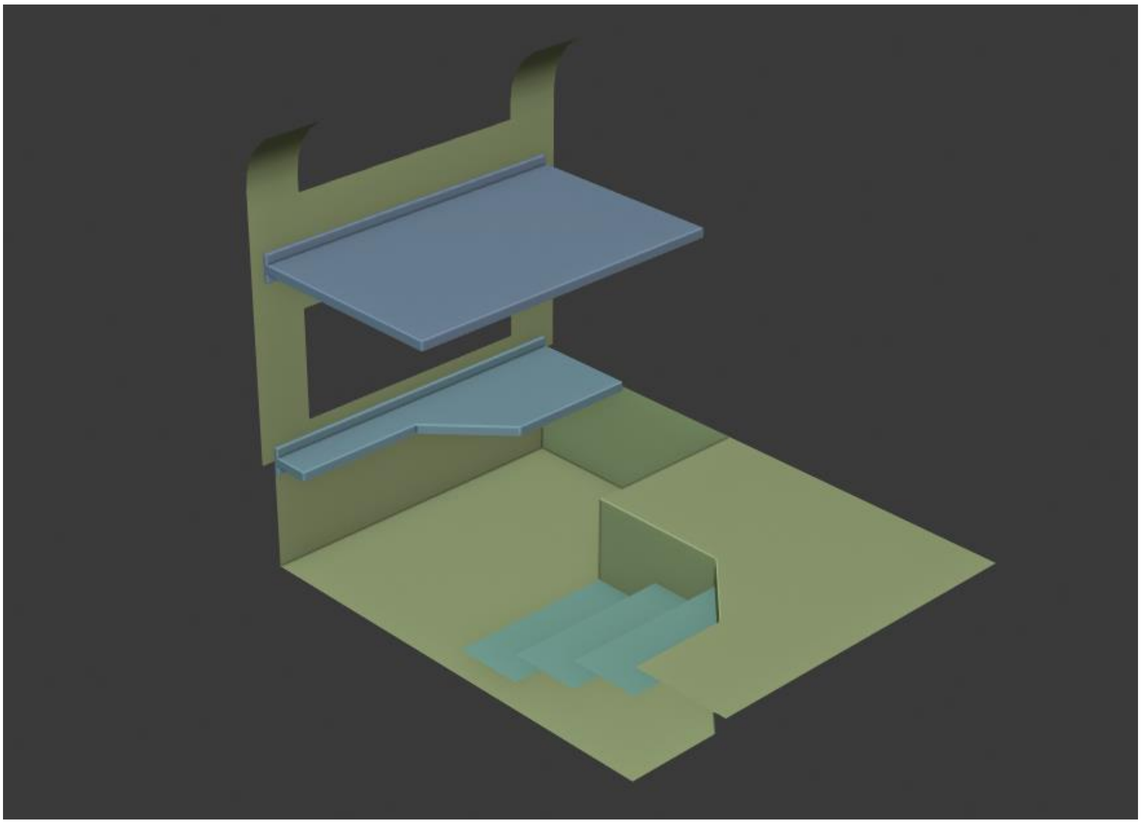
After gathering the reference and having a sound plan of the aesthetics, the process of creating the blockout began in blender (picture 35). Having a well thought out blockout is important before moving on to the modeling of each structural piece, as this separates the unique structural pieces from the modular pieces which allow iteration through the reuse of assets. In this stage I wanted to have a base understanding of the space used, without any refined model information. Eventually the interior would have some basic appliances as well as a bed, but at this stage having a bare interior as a blank slate that I could modify continually as I progressed gave better visual clarity. This enabled me to test my ideas, such as the placement of windows and the addition of a loft area through a lot of trial and error in a non-destructive way.



PICTURE 35. First initial blockout of the interior.

4.3 Modelling of the assets

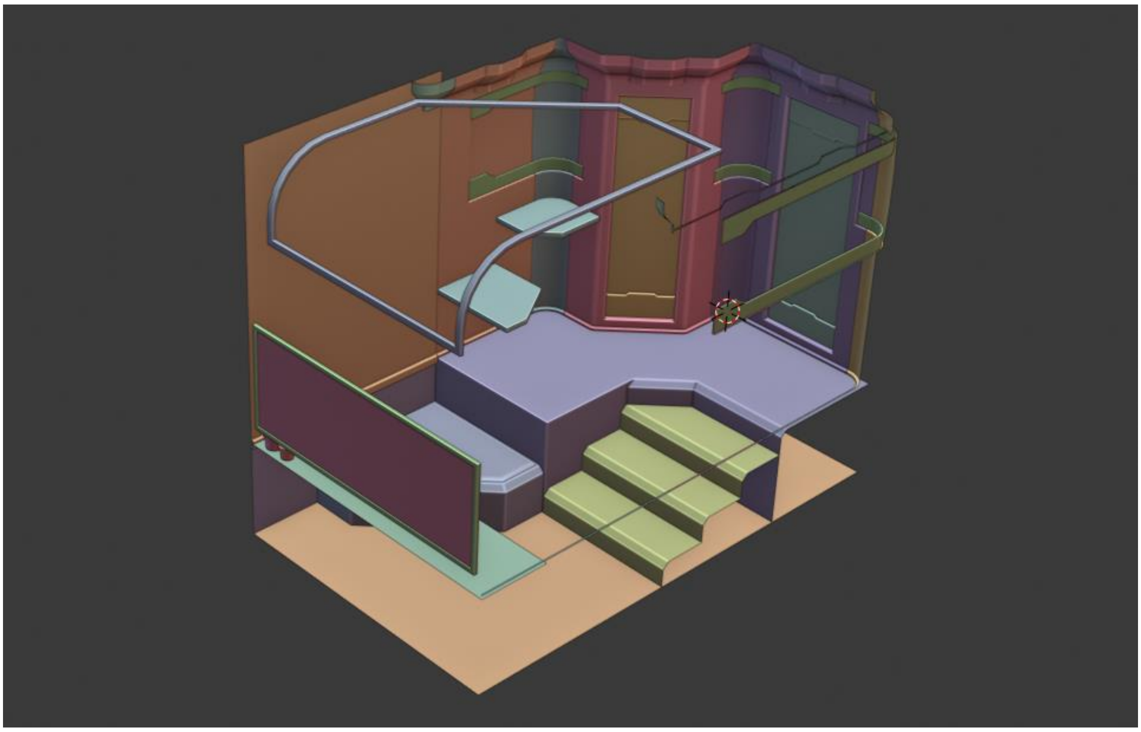
My choice of software for the modelling process was blender as it is the software, I am most familiar with. Blender also has all the tools that I needed for this workflow included in the software in itself and has a continuously evolving community creating addons for different purposes that I knew I could benefit from. Although the tools needed for the workflow are basic and found in other software’s as well, the familiarity of using blender was a clear choice. My plan originally was to begin by taking each piece from the block out and dividing them by the ones that will be modelled as modular pieces and unique pieces. The goal was to have as many modular pieces as possible in the interior as this would eventually give me the possibility to iterate on it in the later stages of the workflow. During this process the pursue of modularity caused the blockout to become too stripped down and it limited the amount of structural variation achievable. In order to add, a loft area where the resident could sleep and a compact lounge area under it, to a compact interior space, the modularity had to be cut down (picture 36). Ultimately cutting down on the modularity to assets that are repeated often, such as the corner and wall assets. This addition of elements made the interior more interesting and gave it a little more sense of space.



PICTURE 36. Blockout of the interior with the new compact loft and lounge area.

After the models had been categorized into either modular or unique, the modelling of each could begin by creating a rough silhouette of the model. In this process the model itself could be thought of as a low poly model as no bevels had been added to them yet and the polygon count was kept low. Saving the low poly versions of the models allowed a basis for traditional workflow later in the project.

Bevels were added to all of the models using modifiers. Modifiers are automatic operations that affect the object’s geometry in a non-destructive way. This gave the possibility to create all the bevels needed automatically as they would have been too tedious to do manually, speeding up the workflow drastically. As the modifiers are non-destructive, they dynamically change when the model itself is modified and can be switched off. I also added another modifier called weighted normal modifier. This changed the normals of the mesh and offered the desired effect achievable with the medium poly workflow in a non-destructive way as described in chapter 3.2.1. The usage of modifiers gave me the chance to continuously iterate on the models during the project. (picture 37)



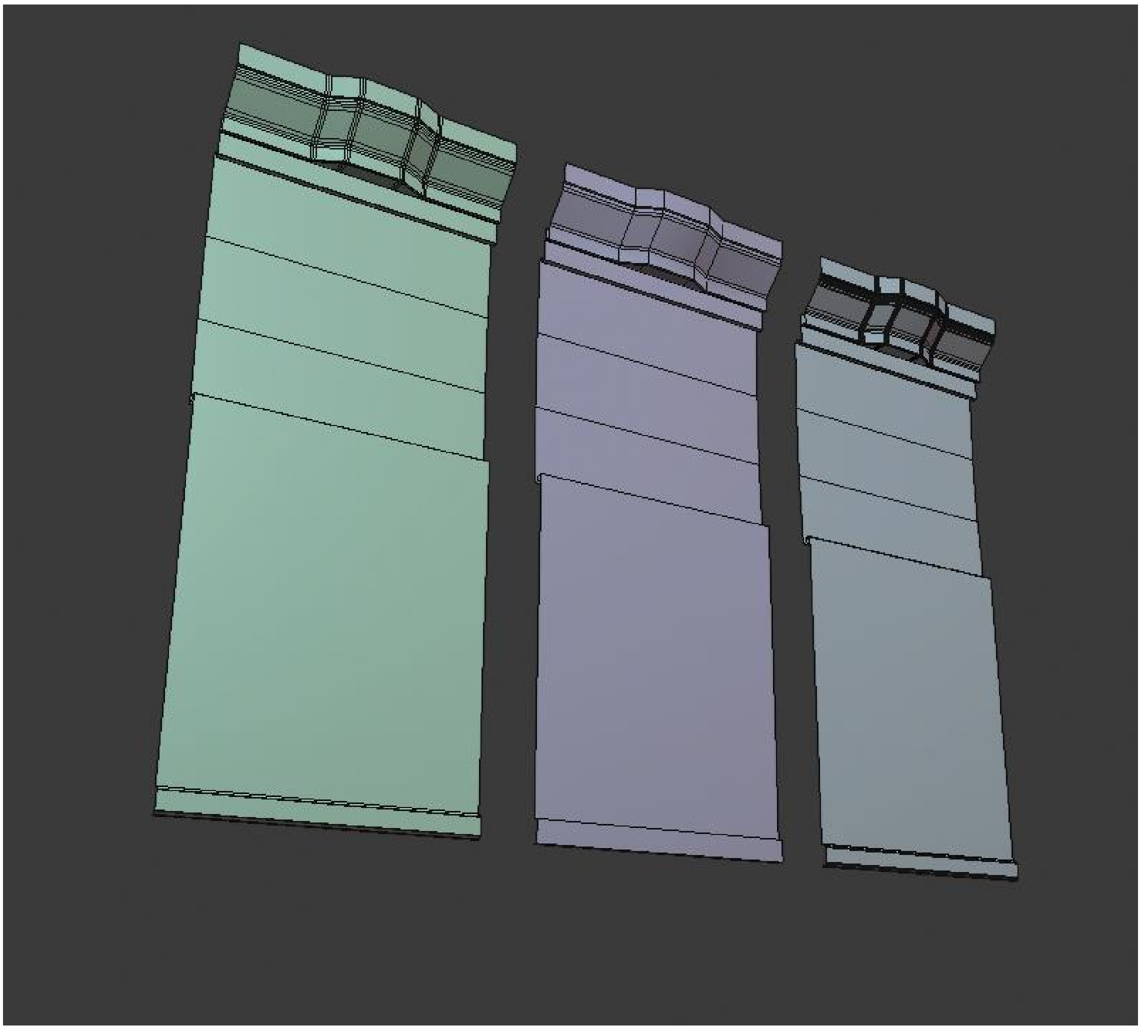
PICTURE 37. Medium poly version of the interior model.

After modelling the majority of meshes in the blockout I continued with some of the props and furniture, such as the bed and desk. A variety of modifiers were used when modelling the bedding and pillows in blender to simulate cloth physics. A combination of both workflows was used for the materials by baking the normal and ambient occlusion maps combined with tiling detail normal and diffuse maps to enable unique mesh detail as well as having the possibility to use high detail tiled textures. This enabled the rapid creation of realistic looking sheets and pillows allowing me to concentrate on other aspects of the modelling process (picture 38). As little resources as possible was used in the modelling of these models as they were used as additional detail in the interior.

PICTURE 38. Baked pillow model (top left) and the low poly model (top right) as well as them situated on the bed in the final 3D environment (bottom).

The professional level results of the modeling stage in the workflow where unexpected considering the time used to create the assets. The detail apparent in the 3D view was comparable to the eventual models. This gave the impression that using the workflow allows for continuous iteration and testing without the need to move on to the next stage in the workflow to see the results of individual models. This came very apparent when working on some of the harder unique models such as the window. The shape of the window was iterated on multiple times and in a traditional workflow, changing the total appearance of a model would take a lot more time.

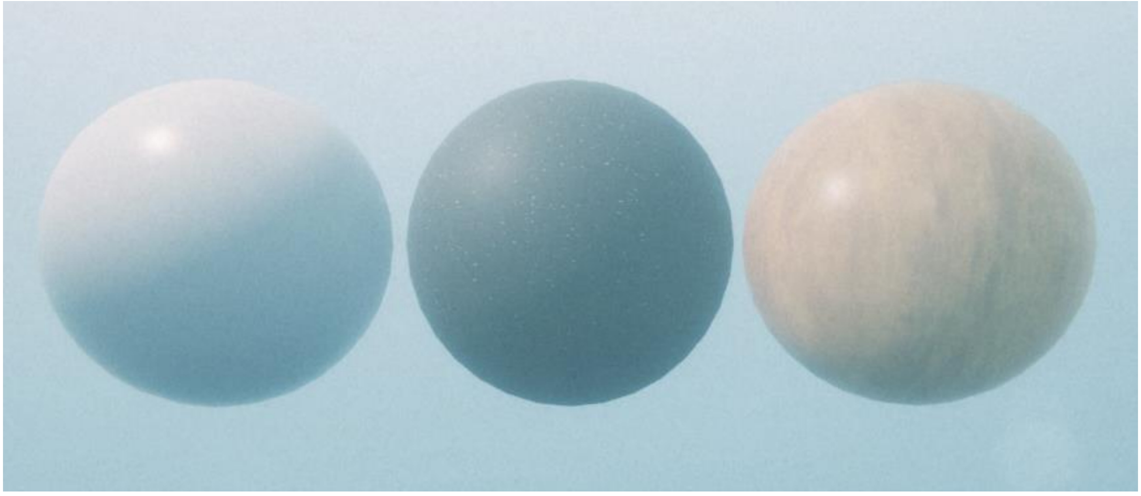
Creation of the models for the traditional workflow version of the interior began by using the previously created models but removing the modifiers used, giving me a low poly mesh to work with. Using a combination of different modifiers allowed me to painlessly create the high poly versions of the models which would eventually be baked on top of the low poly model (picture 39). The baking felt rather tedious after having such a flexible time with the medium poly models.



PICTURE 39. Different versions of the models lined up in blender. Medium poly, low poly, and high poly model.

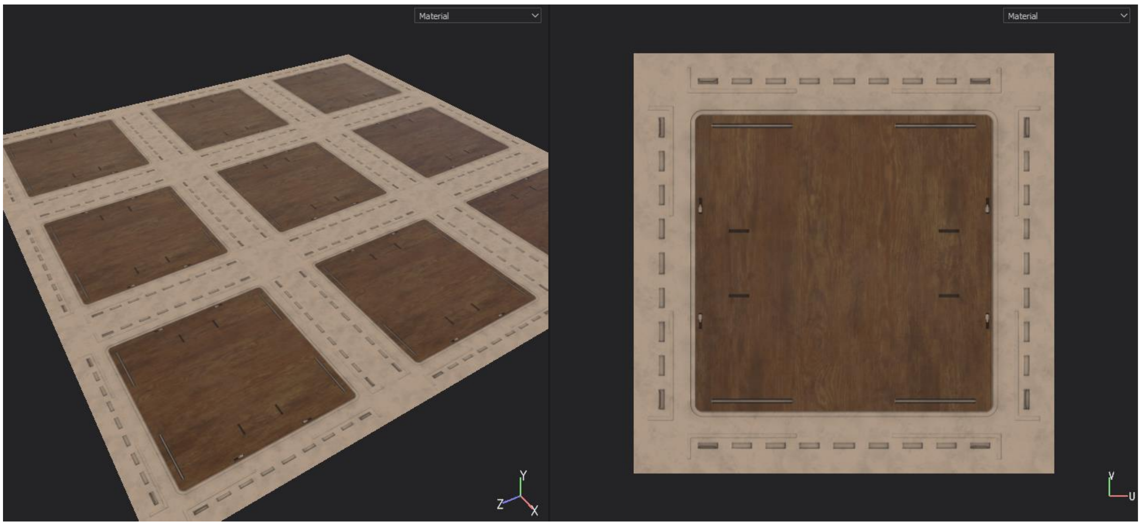
4.4 Creating materials

Having a clear idea of the materials used in an early stage of the workflow was important as I believe the materials used influence the overall look of the interior a lot. The materials used in the project went through multiple iterations. The idea was that the interior is situated in the future and looking at reference there is a lot of aluminium and plastic used in such environments. To break up the monotony of plastic, a more natural wood material was introduced. Eventually the base materials used in the project where variations of plastic as well as a wood (picture 40). Metal flakes imbued in the plastic were used to add visually interesting variation and detail to the plastic materials.



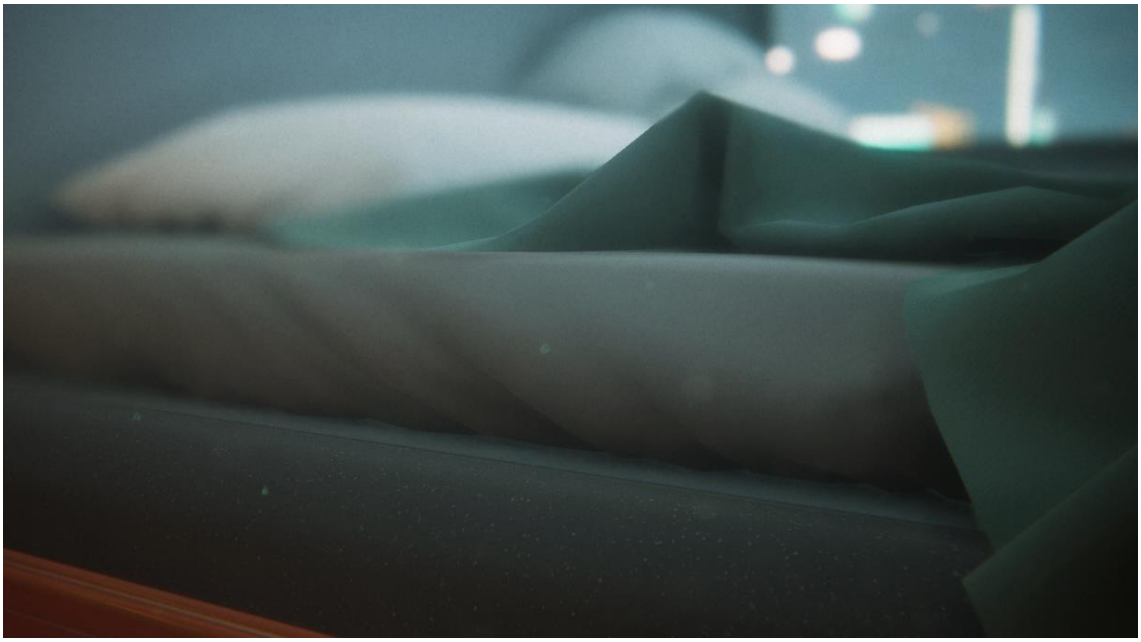
PICTURE 40. Combination of the most used materials used in this project. Light plastic, darker plastic with metal flakes and wood.

The creation of the plastic materials was straightforward as premade materials were used as a basis and combining them with additional height details gave the surface more variation in height and roughness. The creation of the plastic materials was straightforward as premade materials were used as a basis and combining them with additional height details gave the surface more variation. Wood material was a combination of two base materials with an additional varnish on top of it flattening the height details and changing the roughness values to have a smoother appearance.



PICTURE 41. Using a 3 by 3 plane helps visualise the tiling of materials

When creating the materials, I used a 3 by 3 face model UV mapped on to a single texture (picture 41). This enabled me to test the tiling and make any needed modification to the tiling materials inside substance painter. Using tiling materials gave me the chance to have high amounts of detail when looking at the materials from up close. This raises the texel density to higher levels because they are not tied to the detail level of the models UV-maps (picture 42).



PICTURE 42. Tiled materials in final render.

4.5 Addition of details and decals

After having the final medium poly models done, the process of adding details to the models began. During this a lot of research went into how the decals are made resulting in finding an addon for blender called decalmachine which enables the creation of these decals and the trim sheets. The addon itself enables the automation of a lot of the processes that are crucial for the workflow and otherwise tedious if done manually. Some of automated steps are the creation of the trimsheets including the combination and placement into the trimsheets. This sped up the workflow substantially and gave me a lot of creative freedom.

Using the bed as an example, the process began by placing decals on the surface of the bed model (picture 43). During this process I believe it is important to consider the number of decals added as excessive addition of decals can crowd the model and would not be aesthetically pleasing. Leaving some room for empty faces gives the beholder a spot where they can rest their eyes and is great rule for modelling in general, balancing the amount of details. In addition to this rule, as using the addon made the addition of decals quicker than anticipated, adding decal details per function became another rule. When a decal detail did not have an apparent function, it could be left out.

PICTURE 43. Bed model (left) without decals and with decals(right).

When the decals where satisfactory they were exported using the convenient export function in the blender addon. This gave me the chance to export them as a separate combined model with a single texture atlas keeping the model optimised. The actual texture atlas needed some modifications to have it compatible with the real-time engine but otherwise it was very straightforward. This process did not amount to any major problems as it was well documented with the addon.

When creating the traditional workflow version of the bed model the same base model was used that was created during the modelling stage. Bevels and weighted normal modifiers were removed to get to the actual low poly model in blender. The high poly model was made by adding more polygons to extenuate the low poly silhouette until satisfied with the result. Details, such as the rivets and panels, were added to the high poly model in the next stage using the medium poly decals as a basis to keep both models visually comparative. Baking of the high poly details on to the low poly model and texturing was done in substance painter using the same materials that were made earlier. After baking the unique lowpoly model was finished with the same details as the medium poly model but instead of using tiling materials or decals it had one unique 2k texture.

4.6 Assembly of assets in unity

Testing 3D assets in a game engine is an essential part of any workflow and should be done at different stages of the workflow. Once the materials were setup for the models, the process of assembling the environment in Unity began. Unity was chosen as the real time engine because of my prior experience using it and because of the recent inclusion of the high definition render pipeline, allowing for a variety of graphical advancements. This enabled me to use a lot of new shaders, like the decal shader. The environment was imported as a blender file as this gave the possibility to further modify it on the fly without the need to reimport after every change. Blender files are automatically imported as FBX files inside unity and removes the hassle of importing them manually. Materials were added on to the models inside unity. During this process I iterated with different variations of materials to get the look I was after.

After the materials were done for the models it was time to add materials for the decals. During this process there were some difficulties as the decal shader that came with unity had a selection of texture combinations that were unfamiliar to me. This required a lot of trial and error, but eventually the decals started working correctly. The decal shader that came with unity was made to be used with projected decals and thus was not compatible with the mesh decals I was using out of the box. The decal texture map masks needed modifications that required a redo of most decal texture maps. Once this was done the process of using decals was very straightforward.

As the environment was planned to have a lot of natural light in the interior using the large window, the absence of an outside environment made the scene look rather bland. To add some life to the background free building assets were used to populate a large environment adding emission textures to indicate some life inside the buildings. The aerial perspective gave the appearance of an atmospheric fade out of buildings adding to a futuristic appearance giving me the desired look of a future city (picture 44).

PICTURE 44. The exterior environment for the project.

To finalize the look of the scene a variety of warm lights were added into the interior to add contrast between the cold light coming from the outside and the warm interior. A variety of postprocessing effects were added to give the environment the desired sci-fi look, such as chromatic aberration and bloom. A drone humanoid character was also added into the interior to visualize the size of the space.

4.7 Final result

The medium poly workflow provided the flexibility to iterate on the models constantly during the creation of the project. This in turn gave me the chance to be creative and to concentrate on the visual aesthetics instead of the technical side. The amount of detail that the workflow was able to push out a small amount of time was astonishing as the baking of textures was ultimately left out, slicing the time used in the creation of the assets by half. The addition of decals does add into the time used on the assets but is concentrated in the beginning of the project and is highly reusable for other assets. The possibility for iteration further decreased the time used on individual assets. The traditional workflow in comparison felt cumbersome and not at all as enjoyable. Although both workflows have their strengths as creating a model with a lot of intrinsic detail warrants the use of unique textures. One of such cases is when creating smaller props for interiors where usage of the traditional workflow is advisable. The medium poly workflow itself inherently works best in projects that use a lot of hard surface modelling, as noticed during the creation of the beddings for the bed, the usage of medium poly workflow did not bring any clear benefit. Here is a compilation of screen captures taken of the finished environment (pictures 45-47) accompanied with a visual comparison of the workflow in action (picture 48). Using the traditional workflow while modelling the bed unveiled that even when using 4k resolution textures the detail level of the traditional model fell short compared to the medium poly workflow model. The medium poly model with decals used texture maps that were under 256 pixels in size. The combined 4k resolution texture maps of the traditional model took 17 megabytes in drive space compared to the tileable materials and decals that used 1.5 megabytes combined and were reusable in other assets. I believe that speaks for itself in high regards.

PICTURE 45. Screen capture of the finished pod interior in game engine.

PICTURE 46. Screen capture of the interiors lounge area in game engine.

PICTURE 47. Screen capture of the interiors floor details in game engine.

PICTURE 48. Medium poly model (top) compared to traditional (bottom).

5 DISCUSSION

Using the medium poly workflow with decals enabled me to create an interior that could be iterated upon constantly. I think this is one of the biggest selling points for the workflow although depending on the composition of the team working on the project. For a smaller team the flexibility gives the possibility to rapidly create and modify environments and achieve adequate detail levels in the outset of the process. The detail level that is achievable using decals and tiling materials bring the environment to life as using them destroys the repetitiveness. In a larger team composition, the detail achievable vastly overtakes the usage of the traditional workflow, although as I mentioned earlier both workflows do have their strengths and the usage should be assessed in the planning stage as to which is better for the project on hand.

Even though the expected flexibility and detail levels were achieved I was sceptical about the possibilities to iterate during the process. Iterating on large pieces after the models were imported into the real time engine would have been a threshold question when working in the traditional workflow as it would take a large chunk of time, but in the medium poly workflow it was not noticeable and had no impact on the continuity of the project.

I was surprised with the increase in texel density as the detail level, even when looked at very closely, did not show any evident signs of abnormalities that would be prone to happen when creating high resolution unique models with the traditional workflow.

From a performative standpoint I was surprised as to how little materials I was using in the medium poly workflow as the details were all wrapped into one large texture atlas and other materials were low resolution tileable materials. This is expected to save a lot of memory. The increase in the detail level of models did not have a performance impact as the increase was low in the project. I do expect that in a larger environment the incremental increase in detail for a large variety of models would have a performance impact. Although this could be alleviated with the use of quality level of detail assets.

If I would undertake a similar project in the future, I would want to create a larger environment where the optimisation of the medium poly workflow would have a larger impact. Using trimsheets and decal atlases to their maximum potential from a performative and aesthetical standpoint, aiding in the creation of a larger variety of assets that benefit from the modularity of the workflow.

In conclusion I believe the project successfully demonstrated the benefits of using the medium poly workflow and the key differences compared to a traditional baking workflow. During this time of constant evolution of tools and workflows, adopting this workflow that enables the level of flexibility, detail and the possibility to iterate upon at any stages of the workflow is of clear benefit to the artist and the production itself. This aids smaller productions to elevate their production quality to another level.

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